

Panel 5. Origin & Propagation
of Fire



REPORT OF APOLLO 204 REVIEW BOARD

**TO
THE ADMINISTRATOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

**APPENDIX D
PANEL 5**

N.A.S.A. HISTORICAL
ARCHIVES

NO

9389

APOLLO SPACECRAFT

The spacecraft (S/C) consists of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft/lunar module adapter (SLA). The LES assembly provides the means for rapidly separating the C/M from the S/M during pad or suborbital aborts. The C/M forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and comfort of the crew. The S/M is a cylindrical structure located between the C/M and the SLA. It contains the propulsion systems for attitude and velocity change maneuvers. Most of the consumables used in the mission are stored in the S/M. The SLA is a truncated cone which connects the S/M to the launch vehicle. It also provides the space wherein the lunar module (L/M) is carried on lunar missions.

TEST IN PROGRESS AT TIME OF ACCIDENT

Spacecraft 012 was undergoing a "Plugs Out Integrated Test" at the time of the accident on January 27, 1967. Operational Checkout Procedure, designated OCP FO-K-0021-1 applied to this test. Within this report this procedure is often referred to as OCP-0021.

TESTS AND ANALYSES

Results of tests and analyses not complete at the time of publication of this report will be contained in Appendix G, Addenda and Corrigenda.

CONVERSION OF TIME

Throughout this report, time is stated in Greenwich Mean Time (GMT). To convert GMT to Eastern Standard Time (EST), subtract 17 hours. For example, 23:31 GMT converted is 6:31 p.m. EST.

**REPORT OF PANEL 5
ORIGIN AND PROPAGATION OF FIRE
APPENDIX D-5
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD**

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ORIGIN AND PROPAGATION OF FIRE

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Origin and Propagation of Fire Panel, 5. The task assigned for accomplishment by Panel 5 was prescribed as follows:

Conduct inspections, chemical analyses spectrographic analysis of spacecraft, parts or rubble, or use any other useful techniques to establish point of fire origin, direction and rate of propagation, temperature gradients and extremes. The nature of the fire, the type of materials consumed, the degree of combustion shall be determined.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Origin and Propagation of Fire Panel:

Mr. F. J. Bailey, Chairman, Kennedy Space Center (KSC), NASA

Mr. J. Craig, Manned Spacecraft Center (MSC), NASA

Mr. I. Pinkel, Lewis Research Center (LeRC), NASA

Mr. A. Krupnick, Marshall Space Flight Center (MSFC), NASA

Mr. T. Horeff, Federal Aviation Agency (FAA)

Dr. H. Carhart, Naval Research Laboratory (NRL)

Mr. J. Leak, Civil Aeronautics Board (CAB)

Mr. J. Yardley, McDonnell Company, St. Louis, Mo.

2. COGNIZANT BOARD MEMBER:

Dr. R. W. Van Dolah, Bureau of Mines, U.S. Department of Interior, Board Member, was assigned to monitor the Origin and Propagation of Fire Panel.

C. PROCEEDINGS

1. DETAILED OBJECTIVES:

The detailed objectives of Panel 5 are listed as follows:

a. Determine from direct visual examination of the physical evidence available at the scene of the fire, what facts can be established relative to the point of origin and the direction and method of propagation of the fire.

b. Recommend any procedures, analyses, or tests that would be expected to establish additional pertinent facts from this physical evidence.

c. Review or monitor the performance of these procedures, analyses or tests. Review the results obtained and report any additional facts established.

d. Recommend any further action deemed appropriate.

In the performance of this task, the Panel will keep itself informed as to the data being obtained by the other Panels and will make appropriate use of all pertinent information being generated by these Panels. The Panel will give verbal reports of its results to the Board at frequent intervals and will develop its studies with the continuing advice of the Board. It will report its final results and conclusions in writing to the Board.

2. APPROACH:

Acting under the direction of the Board, Panel 5 considered the related problems of identifying the ignition source and establishing the fire propagation course through the Command Module (C/M). While the main course of the fire can be reconstructed with confidence from the available evidence, the identification of the ignition source is more difficult and will require supporting facts derived from relevant laboratory studies. While several ignition sources remain suspect, none have been confirmed and perhaps no positive ignition source will be found because the evidence may have been destroyed by the fire.

This report treats the subject of ignition sources and fire development separately since each is controlled by different factors.

3. IGNITION SOURCE:

In the conduct of its work, the Panel adopted the following points of view regarding the identification of the origin of the fire:

a. A determination of the origin of a fire requires identification of the first combustible to burn and its ignition source. Proof that the identification is correct requires that the following checks be made:

- (1) The observed fire damage following the ignition can be demonstrated or explained.
- (2) The expected rate of the spread of fire and associated pressure rise in the C/M is consistent with pressure and temperature indications recorded during the event.
- (3) All other combustibles are eliminated as being the first combustible to burn by virtue of one or more of the following points:
 - (a) No available source to ignite the combustible.
 - (b) Possible ignition source is known to be inactive at time of fire start.
 - (c) If ignited, fire would not propagate from the combustible to produce the observed damage and the increase of pressure in the C/M.

b. Information was gathered during the post-fire study of the C/M to facilitate the determination of the fire origin according to this plan.

c. Ignition sources pertinent to the C/M include:

- (1) Electric arcs and sparks

(2) Electrostatic sparks

(3) Friction sparks

(4) Spontaneous combustion through the gradual heating of combustible by slow oxidation in thermally insulated zones.

The investigation included an appraisal of these modes of ignition where they are applicable.

d. Areas of the C/M containing electrical lines and fluid-bearing tubes in close proximity have burned and melted away. Therefore, the actual components involved in the start of the fire may no longer exist. Every effort was made to identify original components from the ash to assess their role in the fire start. Careful examination of these components along with related records of electrical, fluid flow and fluid pressure anomalies were undertaken to establish which of the damaged systems were abnormal shortly before the fire began and which damage was a consequence of the fire.

e. It is typical of fires involving energized electrical systems for arcs and short circuits to develop during the fire as insulation fails. Therefore, if the ignition source is electrical, only those electrical arcs, sparks, and short circuits that preceded the fire are meaningful in establishing the probable fire origins. The section of this report containing observations and analyses presents that portion of the investigation devoted to sorting out these questions.

f. One example of wire insulation damage that may have preceded the fire is illustrated by photograph (Enclosure 5-2). The circled area in the figure shows a wire bundle which lies over a bare stainless steel tube that is a waste management line. This tube lies below the aluminum access door to the carbon dioxide and odor absorber compartment of the Environmental Control Unit (ECU). When the door was opened and closed, its lower edge may have chafed the wires of this bundle. There was no chafing guard for the Teflon insulation on these wires; this made them vulnerable to damage. Teflon is particularly vulnerable to cold flow and mechanical damage. Wire splices close by increased the susceptibility of the insulation to chafing damage. Careful investigation showed that the splices were too far from the chafing point to matter. Combustibles in the form of polyurethane foam and nylon netting lay close to the electrical arcs and sparks that would occur if the Teflon insulation were defeated. The same wires damaged by fire are shown encircled in photograph (Enclosure 5-3).

g. As of March 29, 1967, most of the electrical wiring in the C/M had been exposed to view. The ECU had been disassembled. Units containing electrical and electronic gear were examined to see if internally generated flames or incendiary arcs and sparks could have issued from the openings. Only in three instances did the visual evidence justify detailed inspection of the electronic components. These units were the Translation and Rotation Controls and the Central Timing Equipment. Careful examination showed that the damage to these components was a consequence of the fire and thus they are not considered the source of ignition (References 5-1, 5-2).

h. All wiring was inspected for faults and have been judged for their fire starting potential. The locations of these faults were recorded in Enclosure 5-4 and its attached diagram. Those which were clearly the result of the fire have been dismissed from further consideration. The remainder were studied in detail. Results on these investigations are reported in paragraphs i. through m. of Section 5. Items still under investigation will be included in Appendix G after completion.

i. Electrostatic and friction spark ignition possibilities were studied by Panel 8 in a program to establish the susceptibility of C/M materials to ignition by these sources. This is a cooperative effort with Panel 5, which has stimulated complementary work on the ignition process in 100

percent oxygen atmospheres at government and contractor laboratories. The effect of contaminants, such as water/glycol leakage and cleaning solvents on the ignition and fire development processes of C/M materials will be a principal feature of these studies.

j. More than one potential ignition source for the C/M fire may be found in this investigation. Every effort is being made to establish their relative probability as the 012 C/M fire initiator. Laboratory tests and mock-up fires are the principal tools for these determinations.

4. DESCRIPTION AND COURSE OF THE FIRE:

a. Since the course of the fire was determined by the quantity and arrangement of the C/M combustibles, reference is made to the report of Panel 8 in which these are detailed. Briefly summarized, the combustibles contained in C/M 012 included a liquid combustible water/glycol in a widely distributed system, and solid combustibles - mostly plastics in the nylon, polyurethane, and silicone rubber class. The nylon is mostly in cloth form; the others appear as thin films, thick tapes with exposed pile, and foam plastics used largely for heat insulation and protective padding. A view of the Command Module from the hatch, photograph (Enclosure 5-6) shows the distribution of exposed solid combustibles. Throughout this report reference to location of C/M zones will be as viewed through the hatch in the manner of the photograph. The following description of the fire is divided into three stages for reasons of clarity and convenience in describing when the fire probably started and the specific phases of fire propagation.

Stage 1 - Stage 1 began when the fire started, probably some seconds before the astronaut's first verbal indication of the fire at 23:31:04.7 GMT (6:31:04.7 pm EST). This inference is based upon several anomalies in the telemetry data. Stage 1 concluded at about 23:31:19.4 GMT when the internal pressure ruptured the pressure vessel.

Stage 2 - Stage 2 is the period of greatest conflagration due to forced convection resulting from the out-rush of gases through the rupture. It probably lasted for about 5 seconds; it is estimated that the pressure reached ambient at about 23:31:25 GMT.

Stage 3 - Stage 3 continued from about 23:31:25 GMT through the decaying phase of the fire, when high concentrations of carbon monoxide and smoke were produced, for an undetermined time but which could not have exceeded several seconds.

Note: During the later stages of the fire a localized, extremely intense, fire in the ECU lingered beyond the culmination of Stage 3.

b. From observations of post-fire damage and witness statements, the fire first appeared to be at the lower portion of the left side of the C/M, presumably near the lower left corner (Enclosure 5-7). The slow rate of rise of recorded cabin pressure caused by the heat released by the fire suggests that the fire was not intense until about 23:31:12 GMT (Enclosure 5-8). This slow rate of pressure rise is consistent with the view that the early fire was either located in a zone containing little combustible or one containing much bare aluminum structure which could absorb an appreciable portion of the heat. The first significant indication of pressure rise was shown by telemetry data at 23:31:08.4 GMT.

c. By approximately 23:31:12 GMT, the fire had propagated out of its initial confines to involve additional combustibles. Estimated extent of fire following this time is shown schematically in Enclosure 5-9. The presumption is strong that flames along the left wall prevented the Command Pilot, who occupied the left couch, from operating the valve which vents the C/M to the ambient atmosphere. Such operation of the valve was an initial step in the established emergency fire procedure. However, this emergency procedure would have been to no avail because the venting capacity of the cabin pressure relief system was too low to prevent buildup of pressure within the C/M due to the fire. The heavy damage to the upper wall and ceiling in the left front corner, shown in Enclosure 5-10, shows the

intensity of the fire in this area. Since the oxygen concentration in the C/M was above 90 percent the first flames would be hot, bright, and relatively smoke free. They would rise vertically and spread out under the cabin ceiling. The Senior Pilot, who occupied the center couch, had the responsibility of unlatching and removing the hatch. The Senior Pilot's harness buckle was found in the latched position in accordance with standard procedures.

Some burning of the lower portion of the Command Pilot's suit may have been started by the flames rising from the ECU area and the adjacent nylon debris trap. Tests of nylon debris trap (Raschel net) burning in oxygen show its tendency to sputter off firebrands of burning molten nylon which may be projected several inches horizontally from their origin. These firebrands increase the spread rate over that measured in small scale flame propagation studies of this material, particularly as the convection currents generated by the fire increase. During this period the Inertial Measuring Unit (IMU) record indicated that there was motion in the C/M. The inference is that the Command Pilot was moving energetically at this time, in reaction to the emergency. His communication was interrupted some time before (23:31:10 GMT) or about five seconds after the first recognition of fire. His Cobra Cable is presumed to have been disconnected before this time.

d. Because there had been a history of electric arcs from the Pyro Battery to adjacent structure at the aft bulkhead level in the right front corner, this area was reviewed carefully as a possible site of the fire origin. The main combustible here is the nylon debris trap (Raschel Net) that extends from floor to ceiling. The extensive melting of this net (Enclosure 5-11), visible as fused yellow plastic adhering to C/M components in the corner indicates that the oxygen concentration at the time of its ignition was too low to burn it to completion. For this reason the right front corner is not regarded as the location of the origin of the fire.

e. The second stage of the fire began at about 23:31:19 GMT when the cabin pressure record can be interpreted to mean that the pressure had risen to a range of 29 to perhaps 37.7 pounds per square inch absolute (psia). This is the estimated failure range of the pressure vessel (Enclosure 5-8). This pressure would have resulted from the burning of three or four ounces of nylon, assuming adiabatic conditions. Cooling of the cabin atmosphere by the structure, would substantially increase this estimated quantity.

f. A major failure in the aft bulkhead occurred at the junction of the wall and aft bulkhead in the vicinity of the umbilical (Enclosure 5-12). Cabin gases and flame flowed in the direction of the break in the floor. The flames, debris, and oxygen flowed into the toroidal space between the pressure shell and the heat shield where the thermocouples registered rapidly rising temperature at 23:31:20 GMT. Flames in the toroidal space burned and melted components of the Reaction Control System and the insulation and honeycomb structure of the aft heat shield. These flames also poured from access hatches in the crew compartment heat shield and set fire to combustibles situated on and around the spacecraft at levels A-8 and A-7. These fires endangered pad personnel and impeded rescue.

g. After cabin failure, the gas flowing toward the floor break swept the flames to other combustibles and increased the rate of fire spread markedly. Flames rising above the couches were directed into a horizontal plane to spread the fire over the couches. Examination of the couches and astronauts' suits after the fire indicates the movement of these flames in the manner indicated in Enclosure 5-13. Flame damage to the suits, harness, and helmet visors show that it was most severe for the Command Pilot and least for the Pilot. Witnesses at monitors of the television camera mounted outside the cabin hatch view port reported movement of flame from left to right inside the cabin.

h. Inspection of the pressure vessel floor and aft heat shield, after separation, shows that fragments of Command Pilot's suit were swept there by the flow of cabin atmosphere through the floor break. This implies penetration of his space suit by fire just prior to the second stage of the fire when the convective currents were near maximum.

i. Further evidence that fire crossed the couches from left to right is given by the melting and burning of the leg rest control handle on the left side of the left couch. This handle is formed from aluminum tubing. Tongues of flame flowing over the handle melted and burned its left side where heat transfer would be greatest. The result was a softened and deformed ledge of aluminum on the right side where the heat transfer was less (Enclosure 5-14). A plastic button at the base of the handle shows little deformation and no burning. An aluminum ingot deposited by molten metal from the handle lies adjacent to the plastic button.

j. Some of the fire below the couch also swept in the direction of the floor break (Enclosure 5-15). Fire damage to the three helmet covers lying on the floor below the Senior Pilot's (middle) couch indicated that some of this flame spread around the lithium hydroxide (LiOH) canister storage box to the left of the helmet covers (Enclosure 5-16). Fire damage to these covers is greatest on their left sides where the flames impinged. The fire damage to the helmet covers, shown in this photograph, is consistent with this view of the path taken by the flames at this location. Enclosure 5-17 is a view of the helmet cover which lies closest to the hatch. Because the camera faces the hatch, the left side of the C/M is on the viewer's right.

k. Absence of substantial heat damage to the LiOH canister storage box and the clean underside of the couch above the helmet covers indicates that these flames lasted for only a few seconds. Discrete damage to wire bundles at floor level along the right side of the C/M indicates part of these flames reached completely across the floor.

l. Flames also moved from left to right along the front panel at slightly above floor level. With reference to Enclosures 5-18 and 5-19, which show a portion of the floor in front of this panel, the damage to wire bundles where fire impinged is shown to be greater than to those which lie to their right, as indicated by the arrows on the photograph. The same relative fire damage is apparent on the metal clamp covering the wire bundles, being greatest on the left and least at the right.

m. Substantial fire damage to paint and wiring insulation appears along the front panel, particularly above the batteries, and inverters as shown in Enclosure 5-20.

n. Fire damage lessens with displacement from left to right across the front panel above the floor. The modest damage to paint on the upper right section of the front panel shown in the above enclosure demonstrates this point. Soot marks on the panels around the rectangular protuberances indicate the passage of a smoky flame moving upward and from left to right. Some of this smoky flame was provided by small local patches of Velcro which burned incompletely. A tongue of flame extended momentarily to the two wire bundles in the corner to do the localized damage visible in the photograph.

o. Strong convection currents induced by the flow toward the aft bulkhead break may have swept some of these flames across the front panel. Patches of Velcro on the front panel and the nylon net in the right front corner may have been ignited by these momentary flames.

p. Some of the failed 100 and 900 psia oxygen tubing below the Environmental Control Unit are shown in Enclosure 5-21. This photograph shows separated solder joints and burst aluminum tubing running near floor level below the suit circuit heat exchanger. The adjacent portion of the ECU, which contains the LiOH canisters shown in Enclosure 5-3, revealed broken coolant tubing (upper circle), more failed oxygen lines in the oxygen control panel area, and holes burned through the aft bulkhead and pressure vessel wall. The container for the LiOH canisters and adjacent structure show severe damage from a hot, sustained fire.

q. The third and final stage of the fire followed the loss of pressure in the C/M through the aft bulkhead break. The remaining cabin atmosphere quickly became too deficient in oxygen to support flaming combustion and heavy smoke was formed which deposited soot on most C/M surfaces as they cooled. High concentrations of carbon monoxide also developed rapidly at this time. An intense

fire lingered under the ECU and the water and oxygen panels. There, broken oxygen and water/glycol lines continued to supply oxygen and fuel from the supply tanks to support the fire that melted the aft bulkhead and burned the adjacent aft heat shield in this area.

r. Inspection of components taken from many areas of the C/M panel shows momentary penetrations of hot gases and flame through unsealed openings. These penetrations were probably assisted by the rapid increase in pressure difference across the face plates. This is associated with the rapid expansion of the hot cabin atmosphere shortly before aft bulkhead burst and the pressure fluctuation that followed the burst. Local melting and burning of potting compounds, wire insulation and plastic electric connectors are evident. Details of this damage by flame and hot gas penetration is given in the enclosures.

s. Flames penetrated zones behind side and overhead panels and traveled for a distance of up to a foot along thermal insulation on water/glycol lines. This fire damage was confined to the insulation along which the fire traveled. Such fires could cause crippling damage to adjacent electrical components and serious fire spreading can result.

t. In the same areas, there is also a considerable amount of very localized directional burning as would be produced by jets of hot gas or flame. Details of such damage are given in the enclosures.

5. OBSERVATIONS:

a. Observations from the post-fire inspection of the C/M are summarized in the following paragraphs. Supporting photographs are listed. Significant findings which bear on the search for the origin of the fire, the mechanics of fire propagation and the effects of the fire are given. An over-all representation of the areas suffering the most severe fire damage is illustrated in Enclosures 5-3 and 5-21. It is apparent that the highest intensity fire generally emanated from the left front, -Y, +Z, area. Descriptive details, by equipment and/or panels in each of the bay areas, are given in the Enclosures 5-23, 5-27, 5-20, 5-32, 5-35, and 5-37. It must be emphasized that some of the features of the early fire are probably masked by the damage that occurs in the later stages of the fire.

b. Fire started near the left-front (-Y, +Z) corner in the area adjacent to carbon dioxide and odor absorber compartment. Boilerplate mock-up tests conducted at MSC with a fire starting in this location showed a history very close to that deduced from an inspection of the damage to C/M 012. The pressure development associated with mock-up fire correlates well with the pressure-time trace recorded during the C/M 012 fire.

c. The following observations were made of the flame propagation and damage to the three couches. In general, there is no visible structural damage of the aluminum couch structure and sheet material except for, in some cases, destruction of the anodized coating.

(1) Conditions - The sooting patterns reveal that the "as-found" positions of the seat pans, lower leg rests and foot rests were the same as when the sooting took place: (a) The keyways of the trunnion locks are sooted except for the left couch 170° keyway, the center couch 96° keyway, and the right couch 264° keyway, (b) The lock pins and their receptacles are sooted or not sooted to conform to these same positions, and (c) The foot rest side panels are sooted to indicate no motion from their present positions after sooting.

The foot rest area of the three couches offered several indications of decreasing temperature from the left side to the right. The nylon sheathing material on the foot restraint cables of the left couch is completely gone except for a very small quantity near the swaged ball fittings. Proceeding to the right there is an ever increasing amount of sheathing material remaining on the cables.

The Velcro hook patches on the left sides of the leg rests are melted down completely; whereas, the ones on the right side, although heat damaged, retain their identity as hook material.

The foot restraint straps follow the same left to right pattern. Those of the left couch are completely melted away. The straps of the center couch are present, but semi-melted, the left one still attached at both ends, the right one connected only to the right arm. The right couch straps are completely connected; they are partially melted but to a lesser extent than those of the center couch.

It is noted that the left lower arm rest pad assembly of left couch had been attached to the lower arm rest tube with epoxy; whereas all others had been attached by six rivets each (three on each attachment bracket). The left lower arm rest pad assembly was the only one separated. Some of the epoxy shows application of heat after separation; all epoxy remained on the tube. The lower arm rest pad assembly was found on the aft bulkhead of the C/M on the -Y side directly under the reentry oxygen bottle. It was inverted. The bracketry at the bracket/epoxy interface was clean. The nylon pad (face down on the aft bulkhead) was badly burned as are all other arm rest pads with the exception of the left pads of the right couch.

The left seat pan lock handle has had the aluminum tube wall melted away at the front formed bend (outer curvature only); most of the remaining portions of the tube show heat cracking. The plastic striker plug on this handle shows signs of flowing and has partially exited the tube although the plug had retained its basic shape. The other two lock handles were not heat damaged nor were the plastic plugs.

The left couch right foot rest has a collection of molten aluminum in its right-hand trough at the foot restraint arm. This aluminum appears to have dripped from the access panel of the potable water tank. This panel is in the +X direction from this foot rest when the rest is in the usual position and the pan lowered to the 170° position. The collection appears to have dripped rather than to have been blown to this area.

All Dacron restraint harness material shows some signs of melting. The bayonets of the left and right harnesses were out of the buckle and sooted after removal. All three bayonets of the center harness are still inserted in the buckle. The center harness had extensive melting of the webbing between the buckle and the three left attachment points. The sooting patterns on all the head rests indicate that the head rest tabs were, at the time of sooting, in the same positions as found following the fire.

The cushioned areas of the seat pans had almost all cushion material burned or melted away with some sooting action taking place under the cushion area. This pattern is completely different from the cushioned area of the back pans which are almost completely clean. The Velcro hook for the back cushions is darkened but still retains its blue color and hook appearance.

(2). Observations

(a) When the couch exposed areas were sooted, the seat pans, foot rests and head rest tabs were in the as-found position, i.e.:

1. Left seat	-170°
Left head rest tabs	-folded
Left foot rests	-extended
2. Center seat	-96°
Center head rest tabs	-left folded, right extended
Center foot rests	-stowed
3. Right seat	-264°
Right head rest tabs	-folded
Right foot rests	-stowed

(b) The hottest area was under and to the left of the left couch foot rests (in the -Y, +Z direction from the foot rests).

(c) There was a directed flame path from the area described in (b) across the left couch seat pan lock handle (and translation controller).

(d) The conditions of the couches indicate that the flame front spread from the left to right (Velcro facing "upwind" highly damaged; Velcro facing "downwind" less damaged under and along the foot rests and seat pans).

(e) There are no major heat sources indicated by couches other than those described above.

d. There is no evidence to indicate that water/glycol from the ECU contributed significant fuel in the first two stages of the fire. After the lines failed it was the principal combustible for the sustaining fire in this area. However, the water/glycol system cannot be exonerated as a potential contributor to an electrical ignition source. Laboratory analysis of ash taken from the aft bulkhead shows presence of glycol and there was a history of prior glycol spills in this area

e. Due to the condition of the carbon dioxide and odor absorber compartments the possibility was considered that an explosion and fire originated in these compartments, resulting from hydrogen produced by a reaction of lithium hydroxide with water and aluminum. However, both of the lithium hydroxide canisters in the spacecraft at the time of the fire were of the impregnated fiberglass variety. They were so constructed that the lithium hydroxide pellets were not in direct contact with aluminum metal. In order to produce significant quantities of hydrogen, liquid water must be present to dissolve lithium hydroxide and bring it in contact with aluminum metal. Qualification data for the dew point of the gas leaving the compartment is 60° F, yet the temperature measured at 23:30:50 GMT was 89° F. Also, the cabin temperature was 76.5° F, hence water could not have condensed in the lithium hydroxide canisters.

f. Electrostatic discharge from nylon or similar material was considered by the Panel to be a remote possibility, it cannot be completely discounted at this time. Consequently, experiments were conducted to assess this possibility. (See Appendix D-8)

g. For simplicity and where practical, the results of investigations of the equipment bays are combined and a summary of conditions and conclusions are presented.

(1) Right Hand Equipment Bay

The instrumentation, wiring, panels, and rear pressure vessel wall were sooted and fire damage was slight. Some debris resulting from fire damage was found on the aft bulkhead in the open areas. The compartment floor under the Earth Landing Sequencer and Circuit Interrupter areas showed moderate fire damage which was probably due to fire sweeping under these compartments to the break in the aft bulkhead. None of this fire damage is indicative of a fire source. Enclosures 5-24, 5-25, and 5-26 visually show the subject area and Enclosure 5-27 is a detailed tabulation of findings.

Based upon visual observations of the extent of damage and condition of equipment, the Right Hand Equipment Bay cannot be considered as the ignition source area even though the combustible materials in this area provided fuel.

(2) Forward Equipment Bays (Right and Left Hand)

The conditions observed in the Right Hand Forward Equipment Bay showed only minimal fire damage (Enclosure 5-28 and 5-29). However, in the Left Hand Forward Equipment Bay (LHFEB) some of the bottom panels received very severe damage due to localized flame impingement originating from the Left Hand Equipment Bay. Heavy sooting in this area occurred during

the third stage of the fire. Based upon the above evidence, the Forward Equipment Bays cannot be considered as a ignition source.

(3) Lower Equipment Bay (LEB)

The conditions found in the upper portion (+X, -Y) of the LEB indicate that the fire damage to the external surfaces of panels and instrumentation was more severe on the left and decreased in intensity as it progressed toward the right. Food panels B through E showed severe heating. Jet effects were observed on the front face of the Guidance and Navigation instruments; however, the electronic portions in the interior were relatively unscathed except for some localized damage due to intense heat. The resultant damage was due to melting and burning of some of the potting compound. In a few cases the wire insulation was damaged. The flame patterns in this area indicated that damage was a result of a secondary fire and hot gases. Enclosures 5-30, 5-31, 5-31A and 5-32 present the detailed conditions found in this area.

In the -X, -Y portion of the LEB, fire damage was found to be more severe on the left and decreases toward the right. The cover plate on junction box (15-1A-52) and an adjacent wire show evidence of arcing. The wiring between this panel and inverter shows evidence of being mashed as well as fire damaged. In the area below this panel, most of the wires are stripped of insulation due to intense heat. The external wiring showing the most severe damage was the biomedical adapter "Octopus" cable, extending across the LEB from + to -Y, and the gas chromatograph cable harness tied to an exposed cable harness above inverter No. 3. These two items are discussed in more detail in Enclosure 5-32.

While the faces of the instrumentation in the LEB showed sever to slight damage from left to right, the interior of the instrument packages showed only superficial damage. In some cases, however, there was observed localized entry of flame and heat into some of the instruments in and around the connectors. Based upon the condition of the instrumentation, condition of the face panels, and interior compartments of the LEB, none of the instrumentation in this area is considered to be the primary ignition source. However, the electrical cable to connector "J-185" in the lower left hand corner was investigated in the laboratory.

(4) Left Hand Equipment Bay (LHEB)

The most extensive fire damage to tubing and wiring was observed in the water panel area and below the carbon dioxide absorbers. Severe to moderate damage to the insulation and some cables was observed in the Environmental Control Unit. Penetrations through the aft bulkhead and pressure vessel wall were found to be a result of a high temperature flame jet. The side panel between the oxygen/water panels and the carbon dioxide absorber melted through and the melt collected on the aft bulkhead in front of the panel. Lithium hydroxide and charcoal were found under this ingot indicating that the carbon dioxide absorbers had failed prior to melting of the panel. Wiring below the carbon dioxide absorbers show possible arcing. Enclosures 5-33, 5-34 and 5-35 show detailed conditions of the LHEB. The left hand portion of the LHEB shows less fire damage than the right hand section. Based upon the conditions observed in the LHEB the right hand portion of this bay cannot be exonerated as a possible fire source.

(5) Main Display Console (MDC)

In general the front panel faces of the MDC showed decreasing fire and heat damage from left to right with the flash angle being between 30° to 45° in the -Y, -Z direction. Some buttons, switches and dial faces showed severe damage. Instrument panel 21 (Enclosure 5-38) shows the type of generalized sooting and damage to electronic components, particularly of sooting and heat entry at the thumb wheel opening. However, except for a few localized heat damaged areas, the instrumentation and electronics only showed superficial heat and smoke damage. The conditions found in and around the MDC are presented in Enclosure 5-36 and 5-37. This evidence indicates that the Main Display Console is not a probable ignition source.

h. The wiring in the Spacecraft was subjected to a meticulous survey under 7x power magnification to detect possible arcing. As a result of this survey of the wire damage, only ten wires were considered as likely ignition sources. All other wire damage occurred during the fire. The ten electrical faults

have been or are under study as possible ignition sources. These possible sources are:

- (1) Gas Chromatograph Cable (Enclosure 5-4, Source No. 3, Coordinates G-15).
- (2) Biomedical Adapter "Octopus" Cable (Enclosure 5-4, Source No. 20, Coordinates E-15).
- (3) Arcing in and under the Carbon Dioxide and Odor Absorber Compartment (Enclosure 5-4, Source No. 15 and 16, Coordinates L-11 and L-14).
- (4) Wires in Channel H (Enclosure 5-4, Source No. 19, Coordinates F-17).
- (5) Wire between Inverter No. 3 and Junction Box C-15-1A-52 (Enclosure 5-4, Source 17, Coordinates G-15).
- (6) DC power to Connector J-185 (Enclosure 5-4, Source No. 3, Coordinates G-15).
- (7) AC power to Suit Compressor No. 1 and No. 2 (Not located in Enclosure 5-4).
- (8) Suit Biomedical Adapter Harness (Not located in Enclosure 5-4).
- (9) Cable Harness to Cabin Fans (Not located in Enclosure 5-4).
- (10) Cable Harness to ECU Instrumentation Power Supply and its mating harness.

i. A detailed study of the disposition of the gas chromatograph cable harness and connector before and during the fire was made (Enclosure 5-23). From observational evidence of photographic enlargements and the condition of the connector it has been ascertained that the gas chromatograph cable did not reside on the aft bulkhead before the fire started, where it was found after the fire, but was in or near the gas chromatograph bay. Metallurgical and spectrographic studies of the 115 VAC wires, as well as laboratory experiments, indicates that the melting of the copper wire within the nickel sheath was a result of external heating, which burned away the Teflon insulation, with subsequent shorting of 115 VAC lines. The results of these events caused molten copper to exude through discontinuities in the nickel sheath. Therefore, as based upon these findings, the gas chromatograph cable harness and connector cannot be considered as an ignition source.

j. The Biomedical Adapter "Octopus" cable and connector were studied visually by microscopic examination. Several areas were observed that indicated possible arcing along the twisted wire pairs of the cable harness. These areas were replicated and submitted to electron microscopic examination at a magnification of approximately 5000 diameters. The photomicrographs of the suspicious areas indicated point source melting and defects in the metal surfaces produced by low energy intermittent arcing. Based upon the degree of melting and the depth and length of these defects it was determined that this type of arcing could not raise the temperature of the Teflon to a spontaneous ignition level. In addition, the number and condition of arc spots along a length of twisted pair of wires indicated that the Teflon insulation had been burned from the cable harness prior to arcing. Investigation of the shielded cable did not reveal any suggestions of arcing; therefore, it is concluded that the wiring in the "Octopus" cable harness did not provide a primary ignition source. X-ray examination, resistance, and continuity checks of the "Octopus" cable connectors were negative and showed no anomalies.

k. The cable harness to the ECU Instrumentation sensor power supply contained both 28VDC Bus A and 28VDC Bus B to provide redundant power. Because of the redundancy, a short in the power conductor of one Bus would not be revealed by the telemetry data from these instruments. Whether or not a short occurred cannot be determined because of extensive destruction of the wire bundle by the lingering fire in this area.

l. In order to provide clarity in assessing the damaged area in the lower left hand area (-Y, +Z) of the Lower Equipment Bay it is necessary to consider several components and the wiring in this area. The subjects are cover plate to C-15-1A-52 and adjacent wiring, the DC power cable to connector J-185 and the Gas Chromatograph Cable Harness, the Flight Qual Recorder, and the extreme left hand portions of the Patch and Auxillary Electronic Control Assemblies (ECA's).

(1) The abraided wire and adjacent cover in front of Junction Box C-15-1A-52 was investigated to determine whether this wire had shorted to the panel and to assess the results if arcing had occurred. Both the wire and the panel were submitted to microscopic and metallurgical examination to determine the extent of arcing and thermal profile. Microscopic examination of the wire revealed

evidence of arcing and that the Teflon insulation had been cut prior to the arcing, as determined from tear fragment remaining on the insulation around the arc site and the decomposition level of the insulation.

(2) A transverse section of the wire was carefully polished in 0.001 to 0.002 inch increments and etched to obtain the grain structure in the unaffected and affected heat zones and to establish the thermal profile. The grain structure revealed that the arc site was localized in an area of approximately 0.1 inch and the fire damage to the wire was exceedingly slight. The cover plate also revealed an arc site in the lower right hand corner (Enclosure 5-31A) under microscopic examination, however, the nylon chafing guard adjacent to the arc point and running along the bottom of the plate received only minor damage as a result of melting due to heat. The rear of the nylon guard closest to the arc point was almost intact.

(3) Emission spectrographic analysis of this panel revealed that it was made of type 2024 aluminum alloy. Hardness and conductivity tests showed that the alloy was in a T-6 condition (type of heat treatment); however, the extreme left side was found to be in a T-3 condition. This indicates that the left side of the panel was exposed to temperatures between 425°C and 475°C but that center and right side were never exposed to this thermal level.

(4) The DC power cable to the J-185 connector which supplies the Medical Data Acquisition System Recorder was found to be damaged where it turns in a right angle bend to run along channel K below the Gas Chromatograph (GC) Bay. This damage was just below and to the right of the Flight Qual Recorder. Microscopic and metallurgical examination revealed that this cable was exposed to the same thermal environment as the Gas Chromatograph cable harness. Therefore, the insulation and subsequent melting and shorting was the result of exposure to a short duration but intense flame.

(5) The Flight Qual Recorder face plate was checked for conductivity profile. The analysis indicated no variation in temper. The Velcro on the surface showed melting primarily with slight fire damage; however, the adhesive was intact and no damage was done to the paint below the adhesive.

(6) The left hand edges of the Pitch and Auxiliary ECA's originally had Velcro, attached to their surface; however, after the fire the Velcro, its adhesive, and panel paint had been completely consumed except for a small amount of adhesive and Velcro residue on the lower portion of the Pitch ECA face plate. It is inferred that damage to these panels was a result of flame jet arising from the ECU area which damaged the cable harness to the J-185 connector and the Gas Chromatograph.

(7) Little evidence was found to indicate that the arc between the cover plate to C-15-1A-52 and the adjacent wire could have been an ignition source, based only on the observations and analyses in the preceding paragraphs. While the adjacent areas to this panel do not show severe damage one cannot preclude the possibility that water/glycol residue on the wiring and adjacent metal parts may have provided a propagation path. It is also possible from the size of the arc spots, and the nylon chafing guard remaining after the fire, to conclude that the resultant flash was too small to have ignited the nylon chafing guard along the bottom of the cover plate. However, the arc could have ignited glycol residues, had they been present, resulting in a flash in the upward direction which in turn ignited the large Velcro patch on the Flight Qual Recorder. Therefore, based on this possibility the arcing in the above area cannot be eliminated as a possible primary ignition source. A series of experiments are in order to establish whether or not the above hypothesis is reasonable.

D. FINDINGS AND DETERMINATIONS

1. FINDING:

Damage to components, wiring and compartments in Right Hand Equipment Bay was found to be superficial.

DETERMINATION:

This bay could not have provided a primary ignition source, even though it provided some fuel for fire.

2. FINDING:

Damage in most of the areas of the Forward Equipment Bays was found to be superficial. Some panels in the Left Hand Forward Equipment Bay received severe fire damage from flames arising from the Left Hand Equipment Bay.

DETERMINATION:

These bays did not provide a primary ignition source.

3. FINDING:

Severe damage to wiring was found at the bottom of the Lower Equipment Bay along the aft bulkhead. Evidence of arcing was found on the cover in front of C-15-1A-52 and adjacent wires. Damage was less severe in the +Y (right hand) direction in this bay.

DETERMINATION:

Electrical arcing in the extreme lower left hand corner of this bay could have provided a primary ignition source.

4. FINDING:

Right hand portions of the Left Hand Equipment Bay received severe damage. Wiring, tubing and components in the carbon dioxide absorber compartment and oxygen/water panel compartment were burned and melted. Penetrations in the aft bulkhead and pressure vessel wall were observed. The carbon dioxide absorber compartment showed heavy fire damage and failure was due to pressure overload and melting caused by the fire in this area.

DETERMINATION:

Electrical arcing in the right hand portion of this bay could have provided a primary ignition source.

5. FINDING:

Main Display Consoles (MDC) showed evidence of heavy fire and heat damage on left side; however, the interior of the instrumentation showed only superficial damage.

DETERMINATION:

The MDC did not provide a primary ignition source.

6. FINDING:

There is strong evidence that fire effects on the couches resulted from fire originating in the Left Hand Equipment Bay.

DETERMINATION:

These couches were not a primary ignition source.

7. FINDING:

The Rotation Controller bore evidence of external heating and indications that flame penetrated the control from the upper rear area of the C/M. The Translation Controller had a large part of the upper rear corner missing which is probably due to the controller being hit by an external object after it had been weakened by flame impingement.

DETERMINATION:

There is no evidence that any failure occurred in either the Rotation or Translation Controllers that could have been the probable cause of fire ignition.

8. FINDING:

The spacecraft was thoroughly searched for unaccounted for objects or other evidence that the fire may have been deliberately set.

DETERMINATION:

No evidence was uncovered that suggested sabotage.

9. FINDING:

Evidence of electrical arcs from conductor to conductor and conductor to structure was found.

DETERMINATION:

No arc could be positively identified as the unique ignition source. Three were found that had, all of the elements needed to cause the disaster. Two of these showed evidence of poor engineering and installation.

10. FINDING:

Investigation of certain panels or components is incomplete. The remaining investigations are primarily concerned with determining functionality and adequacy of design.

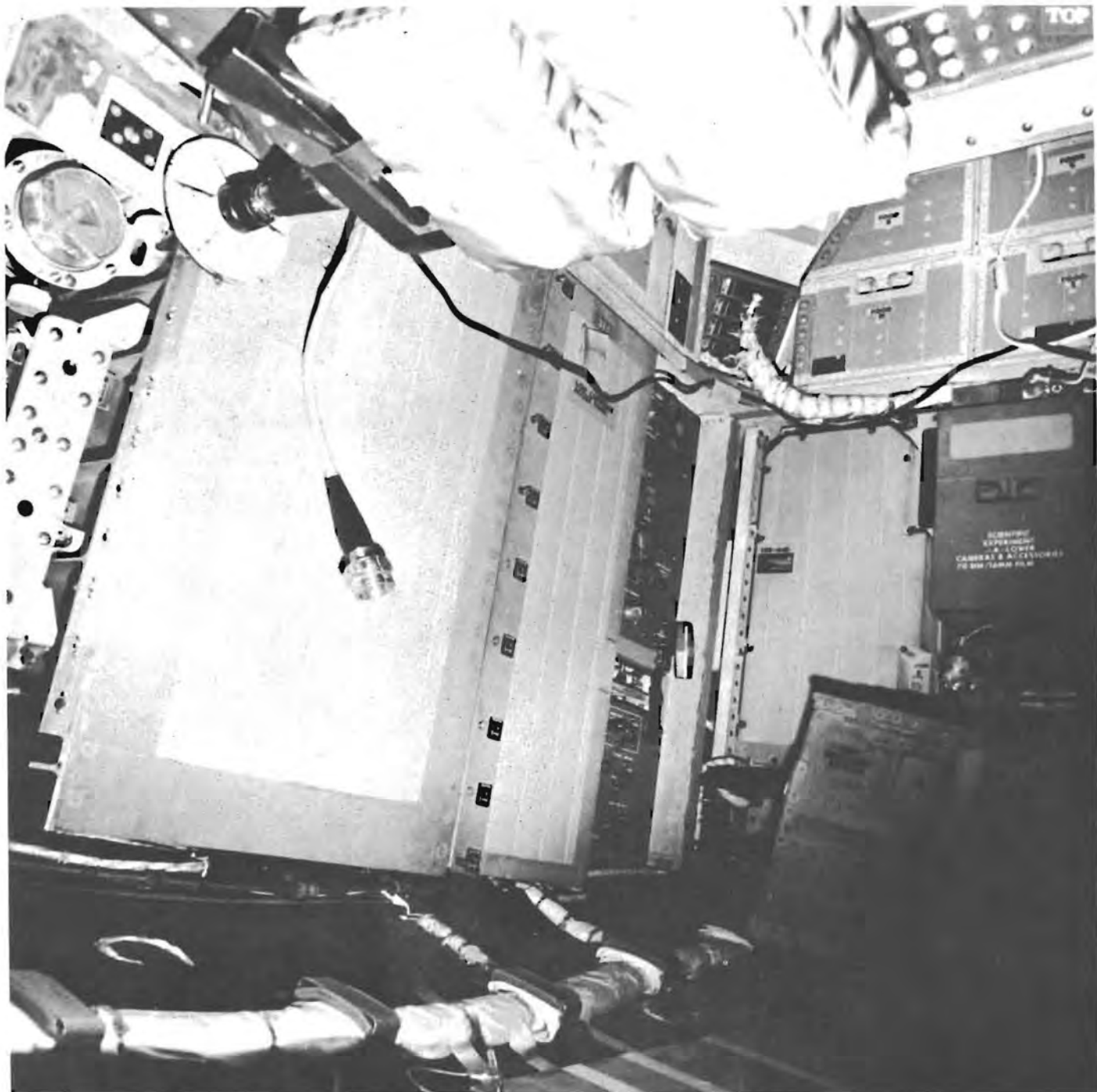
DETERMINATION:

The possibility that these incomplete investigations will uncover information that will modify these determinations is remote.

E. SUPPORTING DATA

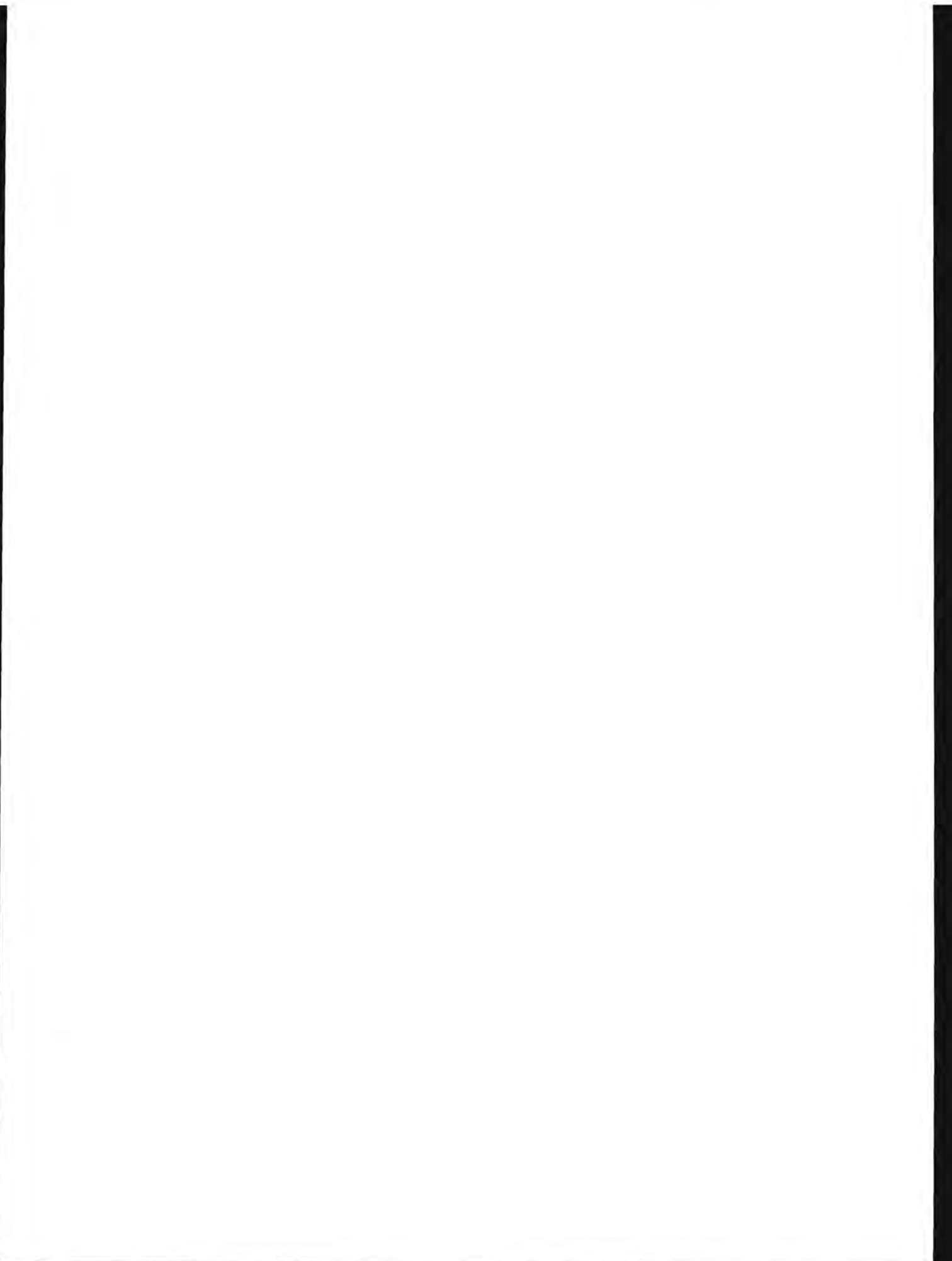
LIST OF ENCLOSURES

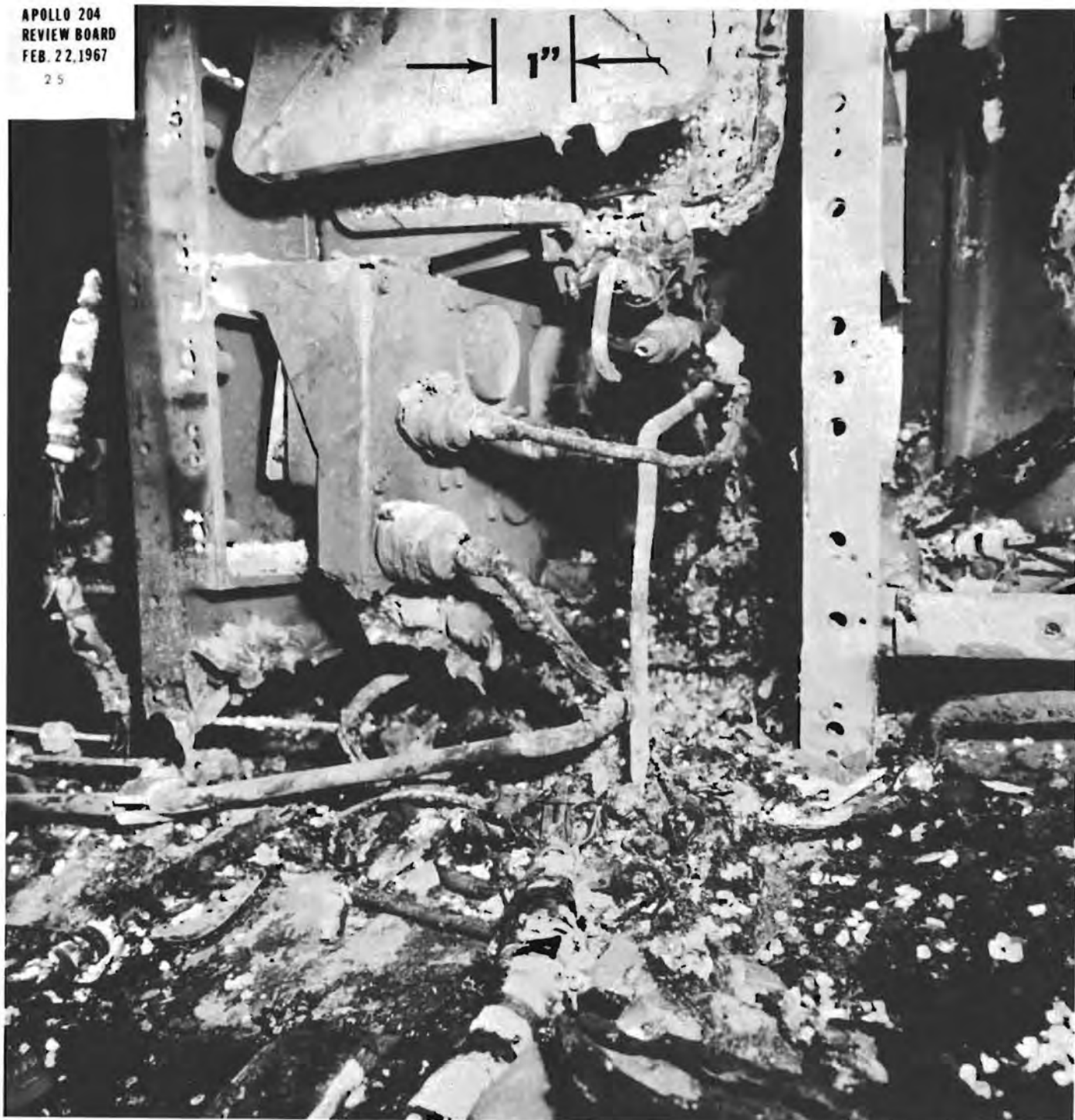
5-1	Not used	
5-2	Photograph	108-KSC-266C-88/6
5-3	Photograph	189-478C-25
5-4	Electrical System Damage and Figure 1	
5-5	Not Used	
5-6	Photograph	189-478C-9
5-7	Photograph	189-478C-10
5-8	Photograph	189-478C-11
5-9	Photograph	189-478C-12
5-10	Photograph	189-478C-13
5-11	Photograph	189-478C-14
5-12	Photograph	189-478C-15
5-13	Photograph	189-478C-16
5-14	Photograph	189-478C-18
5-15	Photograph	189-478C-19
5-16	Photograph	189-478C-20
5-17	Photograph	189-478C-21
5-18	Photograph	A-3-34C
5-19	Photograph	189-478C-22
5-20	Photograph	189-478C-23
5-21	Photograph	189-478C-24
5-22	Not used	
5-23	Gas Chromatograph Laboratory Examination	
5-24	Photograph	17-43C-5
5-25	Photograph	32-7C-11
5-26	Photograph	104-268C-2
5-27	Table - Right Hand Equipment Bay	
5-28	Photograph	17-45C-11
5-29	Table - Forward Equipment Bay	
5-30	Photograph	21-51C-5
5-31	Photograph	23-57C-10
5-31A	Photograph	218-509C-12
5-32	Table - Lower Equipment Bay	
5-33	Photograph	32-7C-8
5-34	Photograph	70-150C-4
5-35	Table - Left Hand Equipment Bay	
5-36	Photograph	32-7C-2
5-37	Table - Main Display Console	
5-38	Photograph	324-666C-12
5-39	List of References	



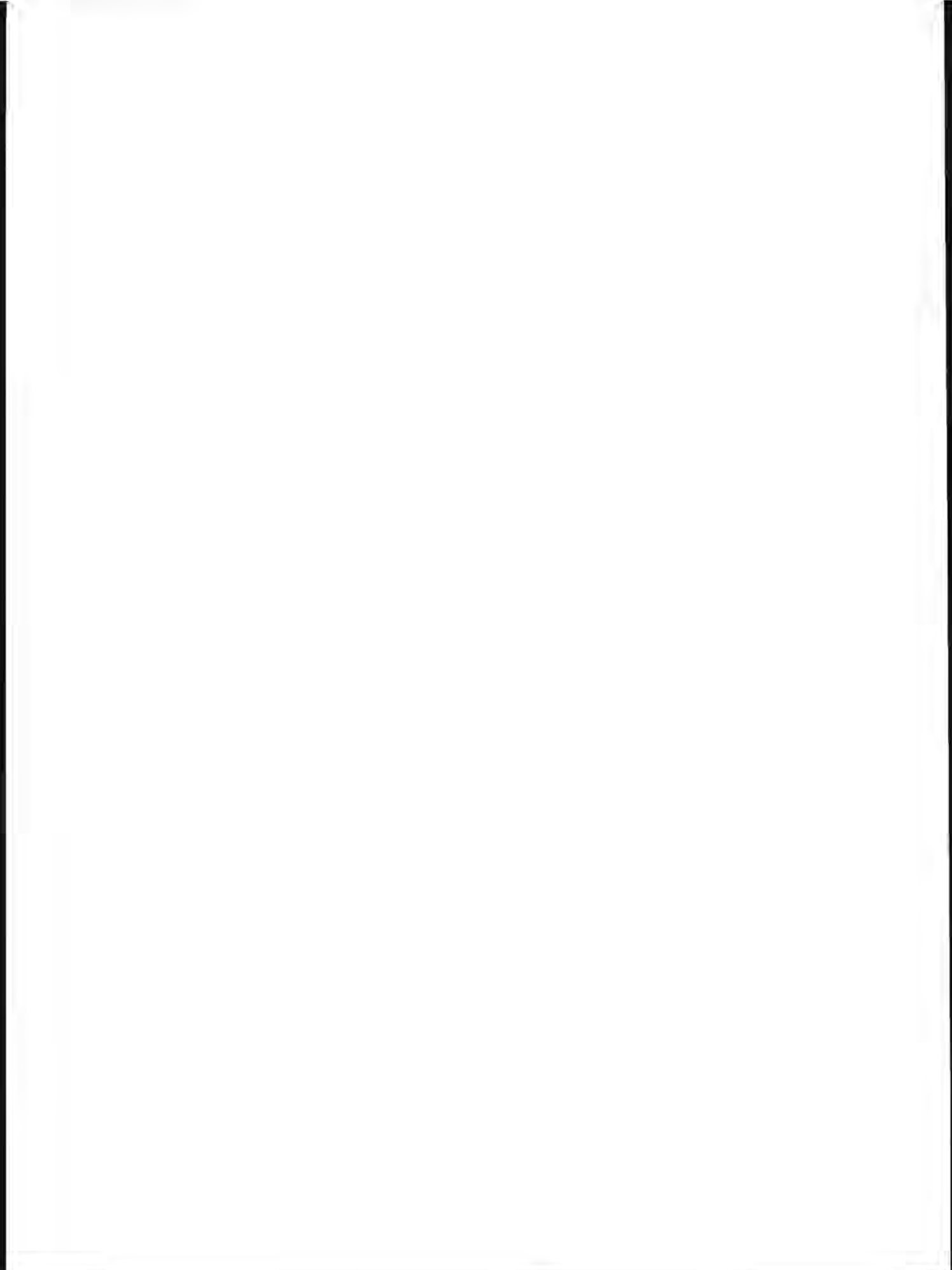
WIRING UNDER CO₂ ABSORBER ACCESS DOOR

ENCLOSURE 5-2





DAMAGED WIRING UNDER ACCESS DOOR



ELECTRICAL SYSTEM DAMAGE

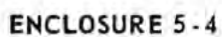
SOURCE NO.	COORD.	DESCRIPTION
1.	K-11	Two small wire runs behind water and oxygen control panel lower LHEB. Run comes up (-X direction) from the aft bulkhead via wire clamps on the rear of the water panel and on the side wall to connections on the O2 control panel. Bare wires are seen in this run approximately 2 inches either side of the wire clamps located on the water panel.
2.	U-33	Cable and connector to small "Black Box" (3 in. X 3 in.) located inside LHEB on the hinged side of the cabin air intake screen. Bare wire is seen at right angle bend in this run where it turns outboard and forward to join main wire harness located on the side wall. Fraying may have been introduced by chafing against hinged door (screen) during repeated opening and closing.
3.	G-15	Outboard harness and inboard harness in LEB run below gas chromatograph installation. Significant damage is seen to have occurred to the outboard run with minor damage to the inside of the inboard run.
4.	F-16	Wire run located in trough below Scientific Equipment B storage compartment in LEB. Bare places are seen in small gage wire on the inboard side of this run.
5.	K-17	Battery instrumentation leads located in a plastic bag on the aft bulkhead under the right hand battery in the LEB.
6.	K-17	wire bundle running in +Y, -Y direction under the inboard edge of the LEB. Bare wires are seen in the top (+X side) of this bundle.
7.	G-19	Center wire bundle of three which run outboard on aft bulkhead between inverter no. 2 and inverter no. 3. Bare wires are seen in the top of this bundle.
8.	K-20	Wire bundle running to connector portion of panel 150 on aft bulkhead. Bare wires are seen for about 5 inches
9.	K-20	small gage wire running to the top row of circuit breakers on panel 150 on aft bulkhead. Fraying is seen to occur about 1 in. from the panel and running several inches back along this run.
10.	L-21	Wire run going outboard on bulkhead underneath sequencer area (RHEB). Bare wire is seen in the top of this bundle at approximately the point beneath the access panel.
11.	M-21	Wire bundle on bulkhead running in &Z,Z direction along the edge of the RHEB. Bare wires are seen in the top of this dundle beneath the location of the red streamer "Remove Before Flight" tag associated with the Earth Landing System (ELS) shorting plug.

See Attached Diagram

SOURCE NO.	COORD.	DESCRIPTION
12.	M-25	Wire bundle running up (S-X) left side of the RHEB compartment and looping to the right. Bare wire is seen along the inboard edge of this run in several places.
13.	N-26	Small gage wires running to small black boxes to the top right of the cavity described previously in source 12 Bare wires are seen on several strands.
14.	N-21	Wire bundle intersection on bulkhead of a&Z,-Z and &Y,-Y run located beneath the edge of the RHEB below cavity described in Source 12. Many bare wires are seen on the top and towards the center of this bundle.
15.	L-14	Wire bundle running outboard under hinged LiOH canister door. fraying is seen in the top of this bundle at the attenuator line.
16.	L-11	Connector panel for ECU in LHEB. Damage to connectors is seen on top side, but less severe on bottom side of these connectors.
17.	G-15	Evidenxe of arc between wire and cover plate of C-15-1A-52 junction box. Wire appeared to press on edge of plate. Nylon chafing guard on cover plate is 3.16. in from arced spot.
18.	L-14	Severely burned residue from wire bundle running under brace for wall between LiOH canister and remainder of ECU.
19.	F-17	Wires severely burned, melted and fused in Channel H.
20.	E-15	Octopus cable had highly localized melting and arcing on twisted pairs.

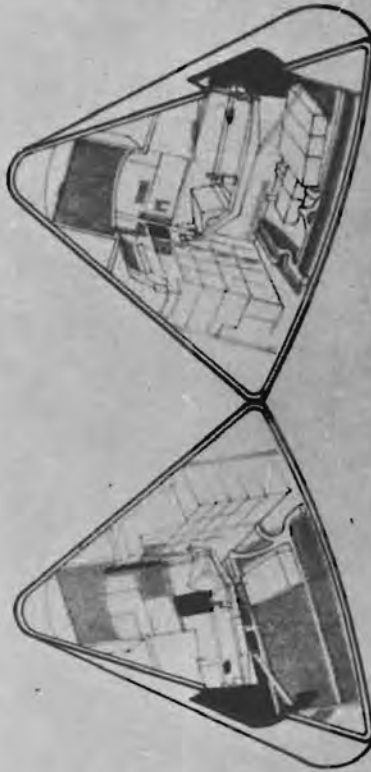
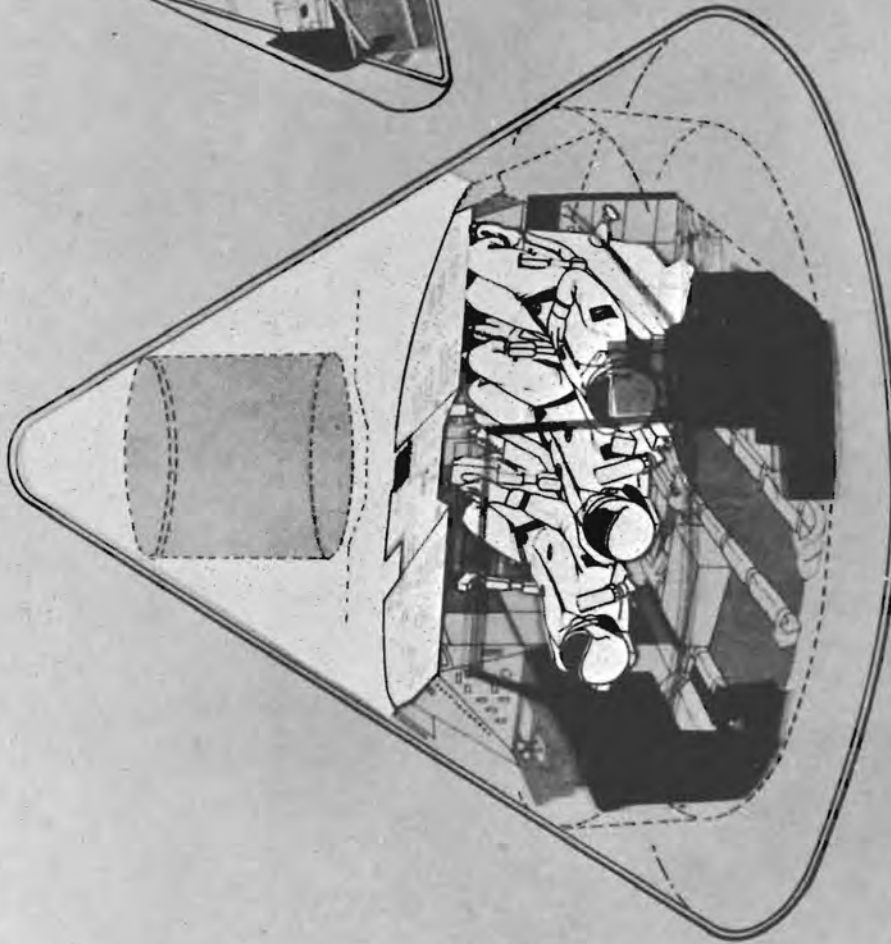
See Attached Diagram

COMMAND MODULE COMPARTMENT
ORIENTATION-BLOCK 1



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EXPOSED NON-METALLIC MATERIALS



VELCRO

URALLANE

RASCHEL KNIT

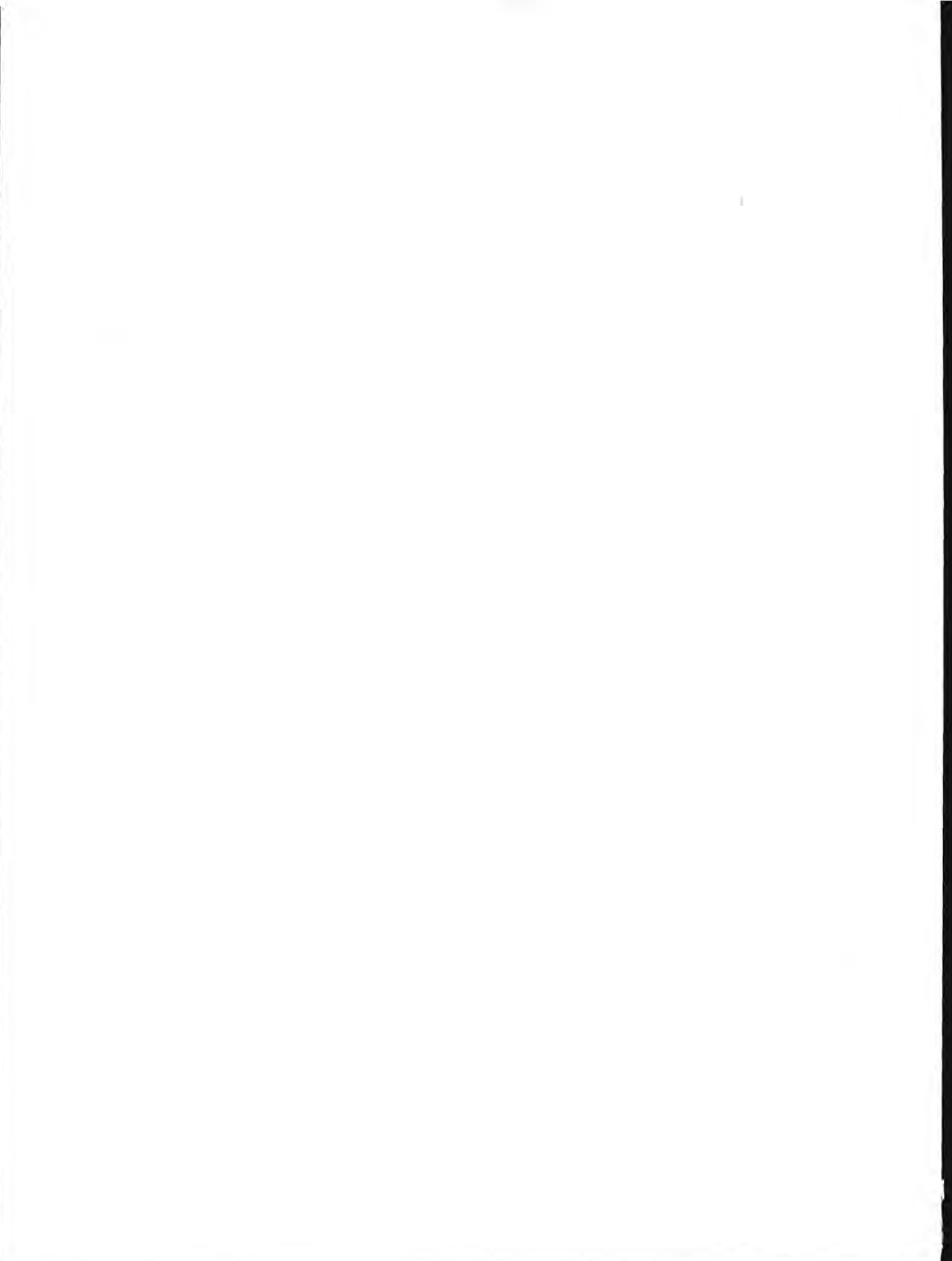
TRILOCK AND RASCHEL COVERING

RASCHEL KNIT (AFT BULKHEAD)

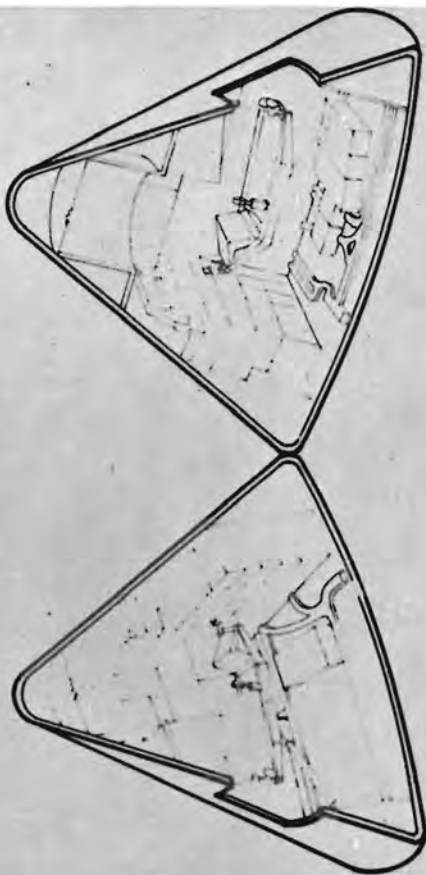
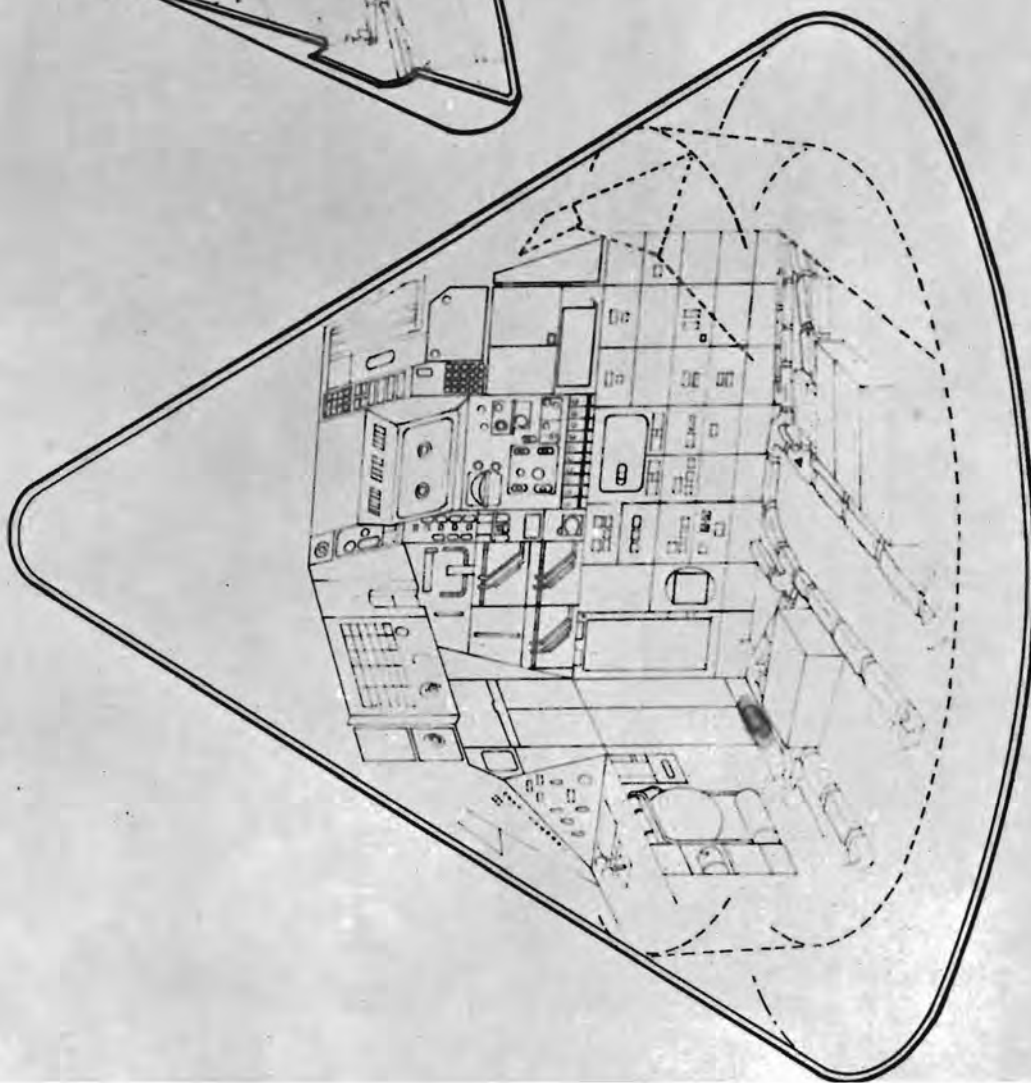
ELASTIC FABRIC COVERING

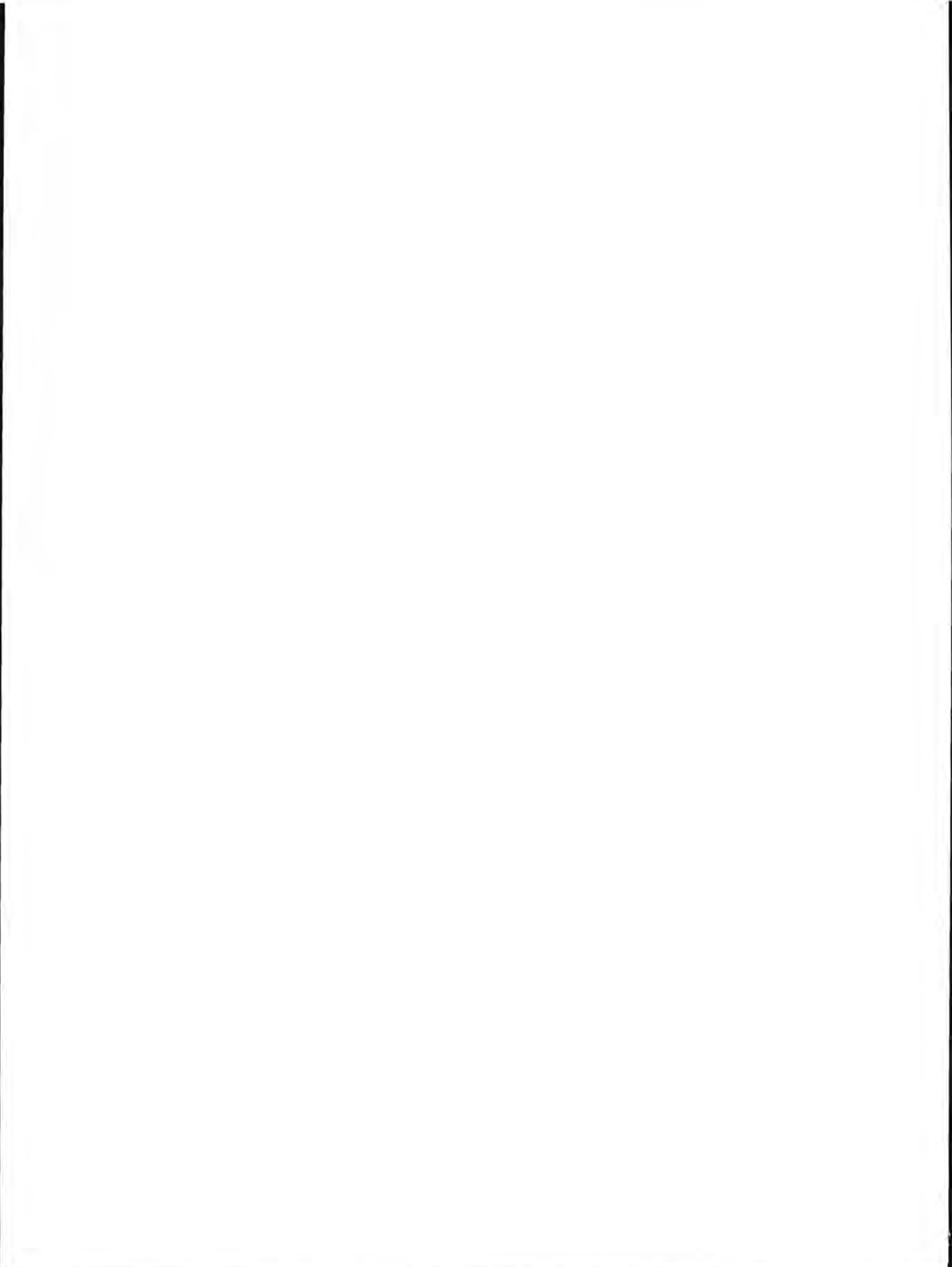
ELASTIC FABRIC COVERING

EXPOSED NON-METALLIC MATERIALS

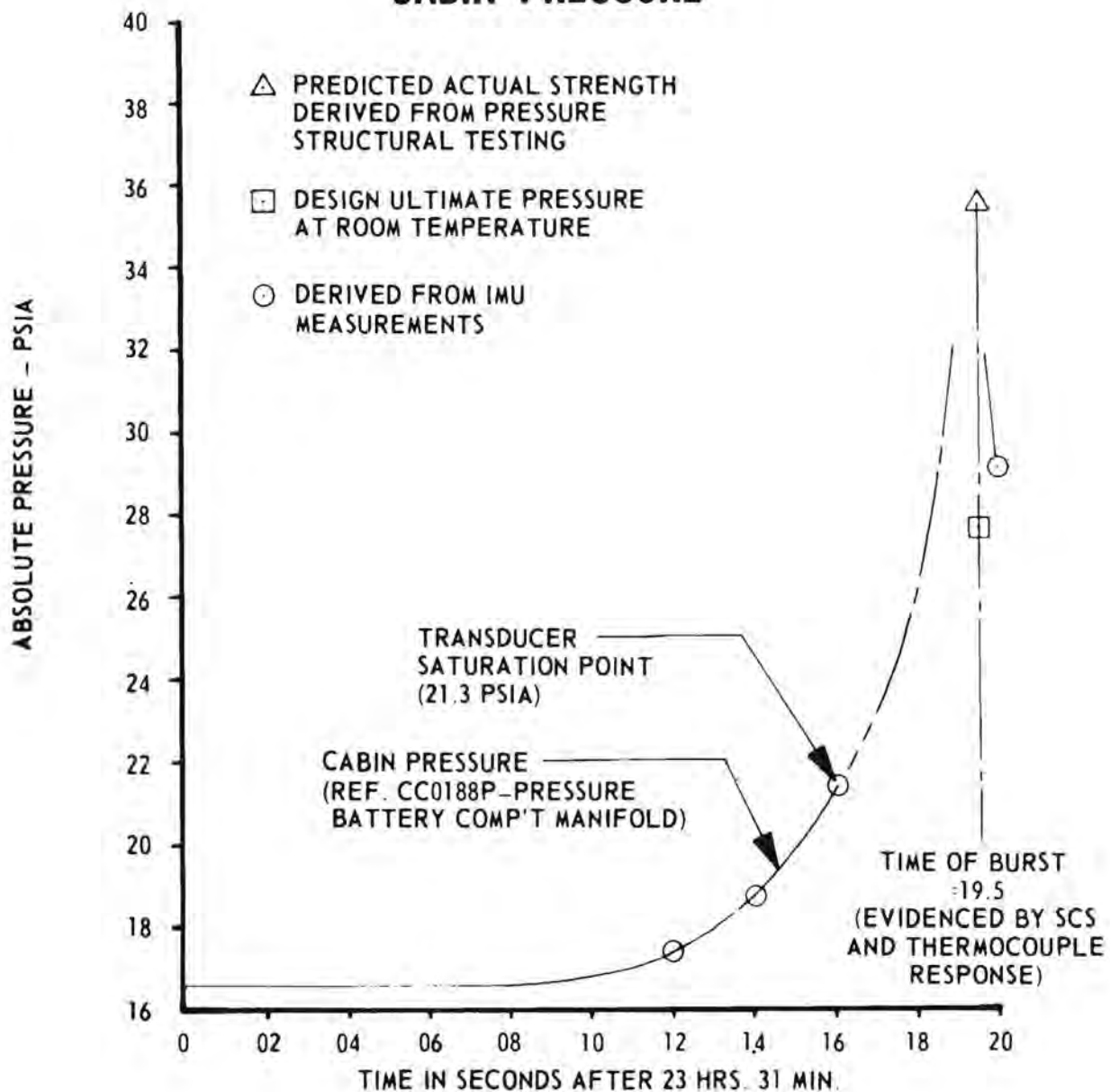


VIEW OF LOWER LEFT HAND CORNER

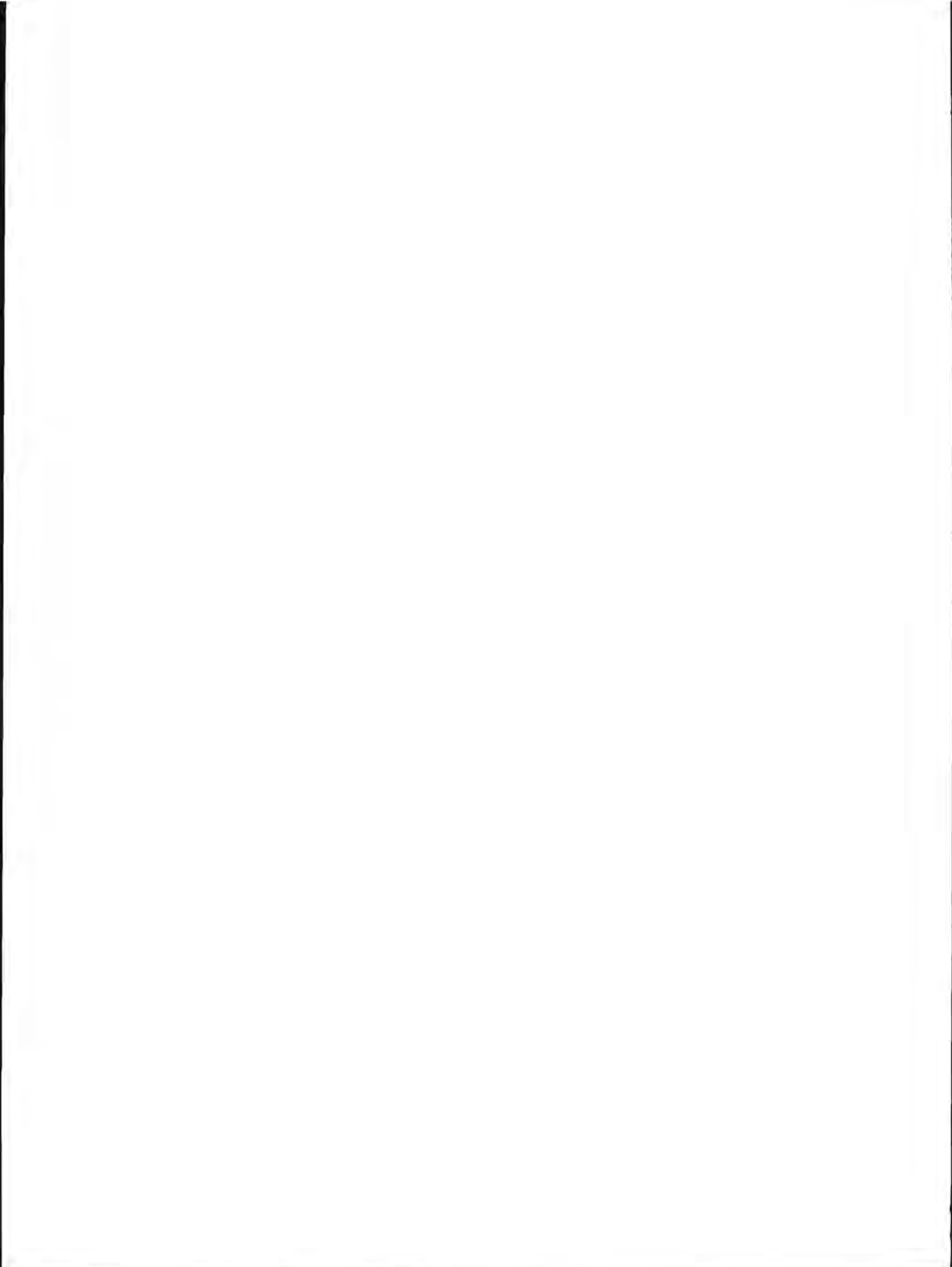




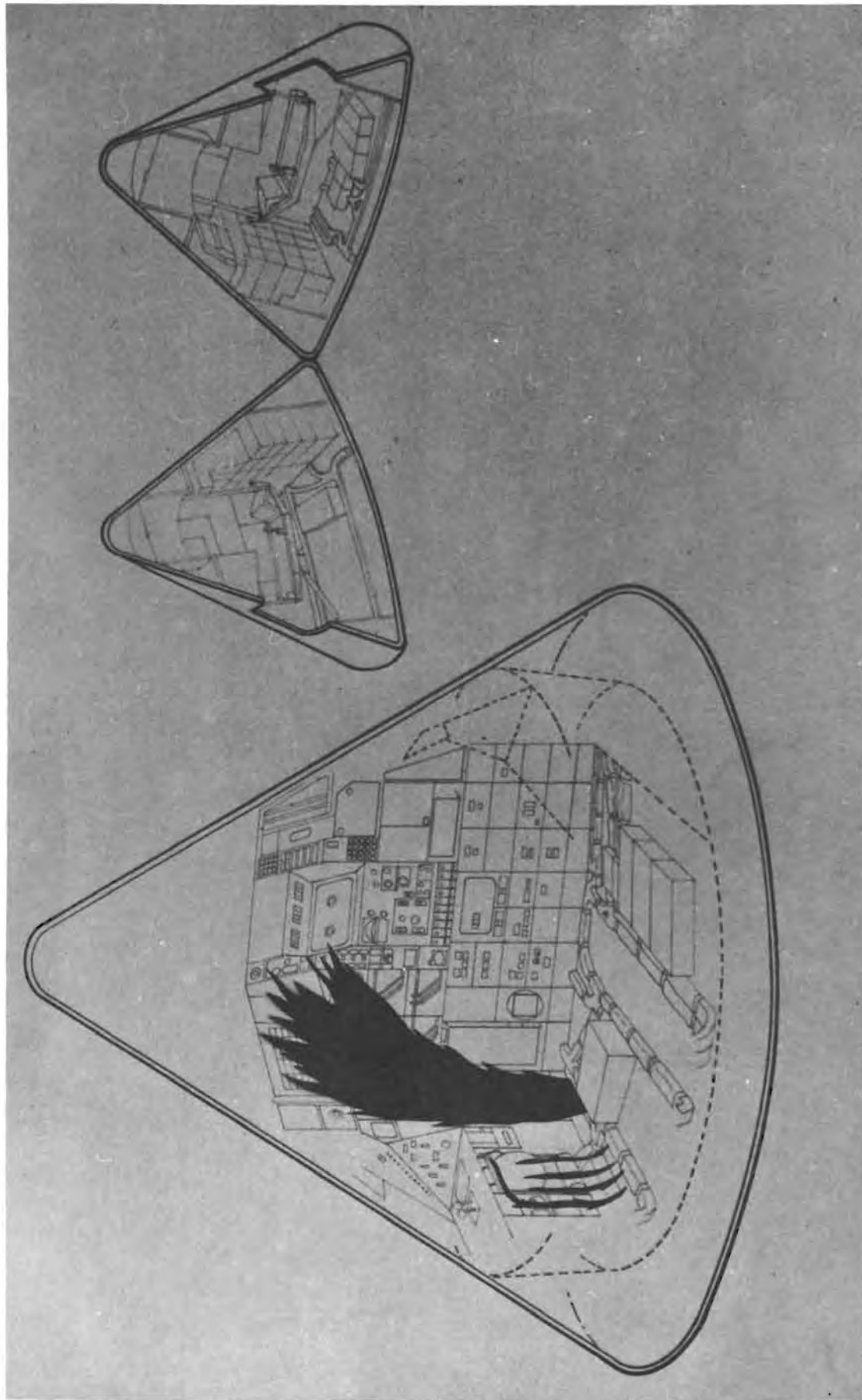
CABIN PRESSURE



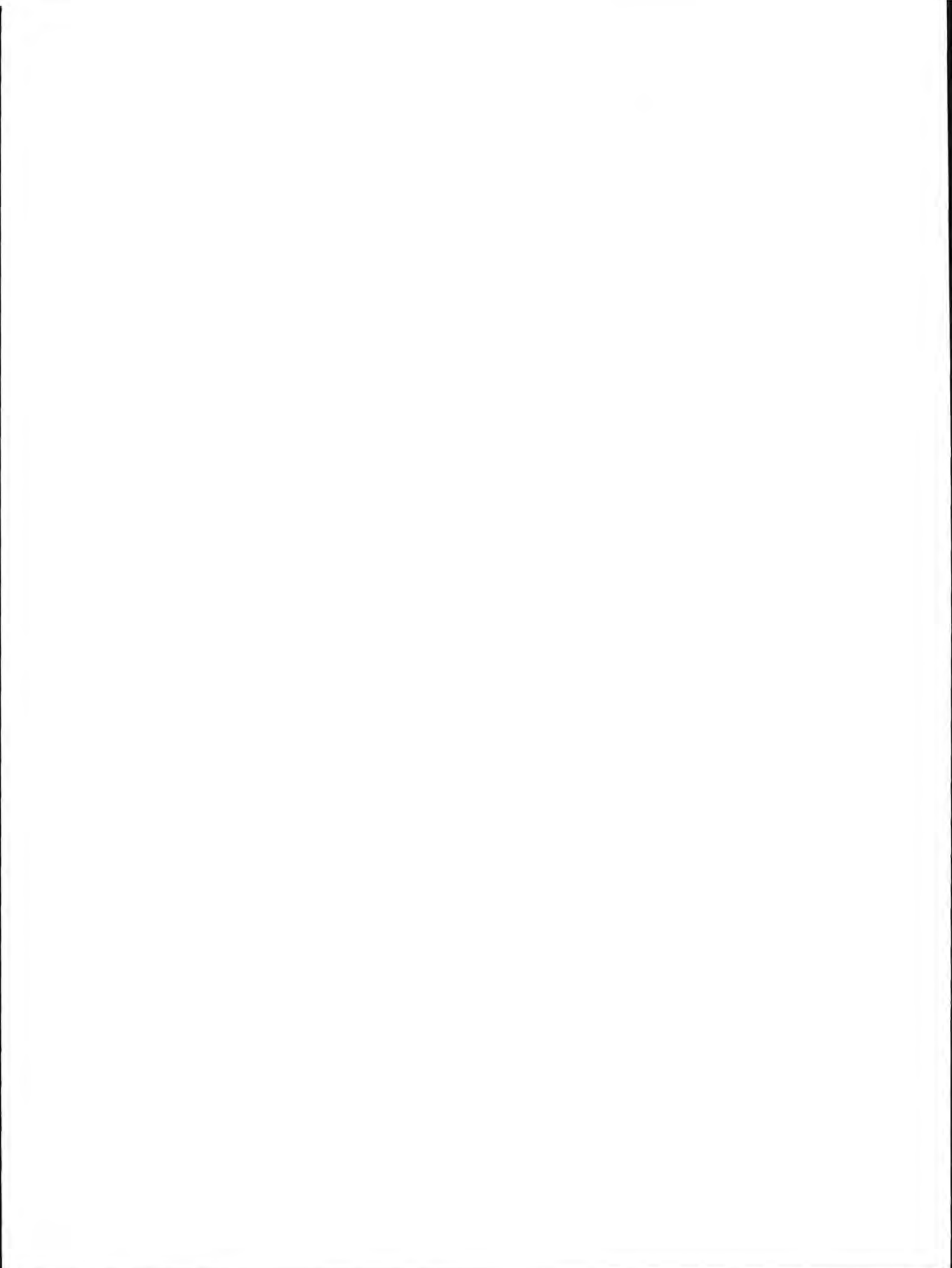
CABIN PRESSURE CHART



C/M FIRE FIRST PHASE



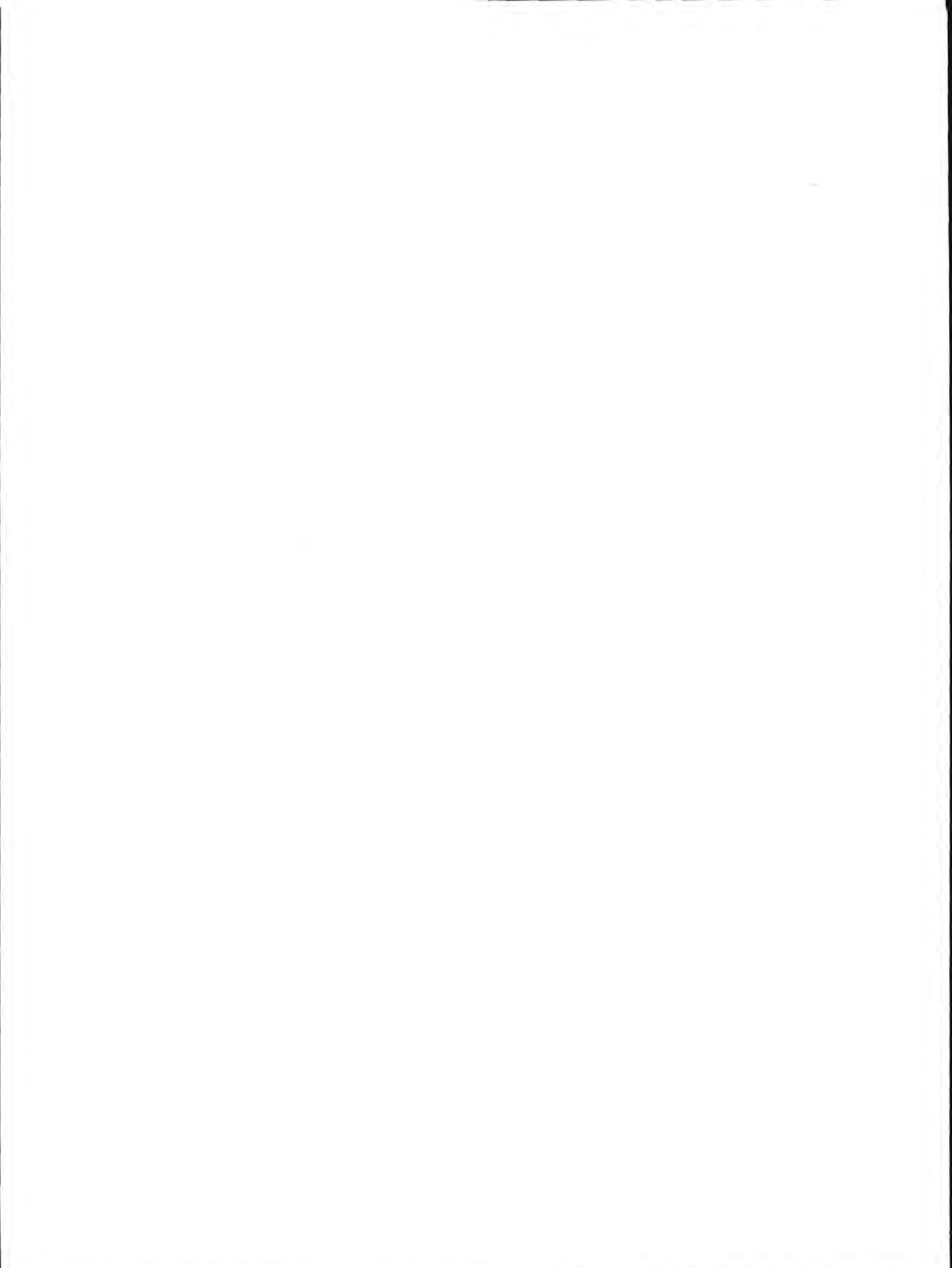
FIRST PHASE OF FIRE





EXTREME UPPER LEFT HAND CORNER BETWEEN LOWER EQUIPMENT BAY
AND LEFT HAND EQUIPMENT BAY

ENCLOSURE 5-10

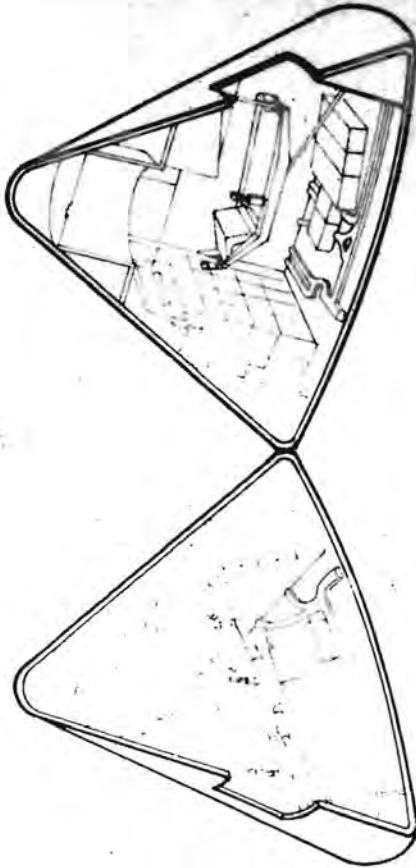
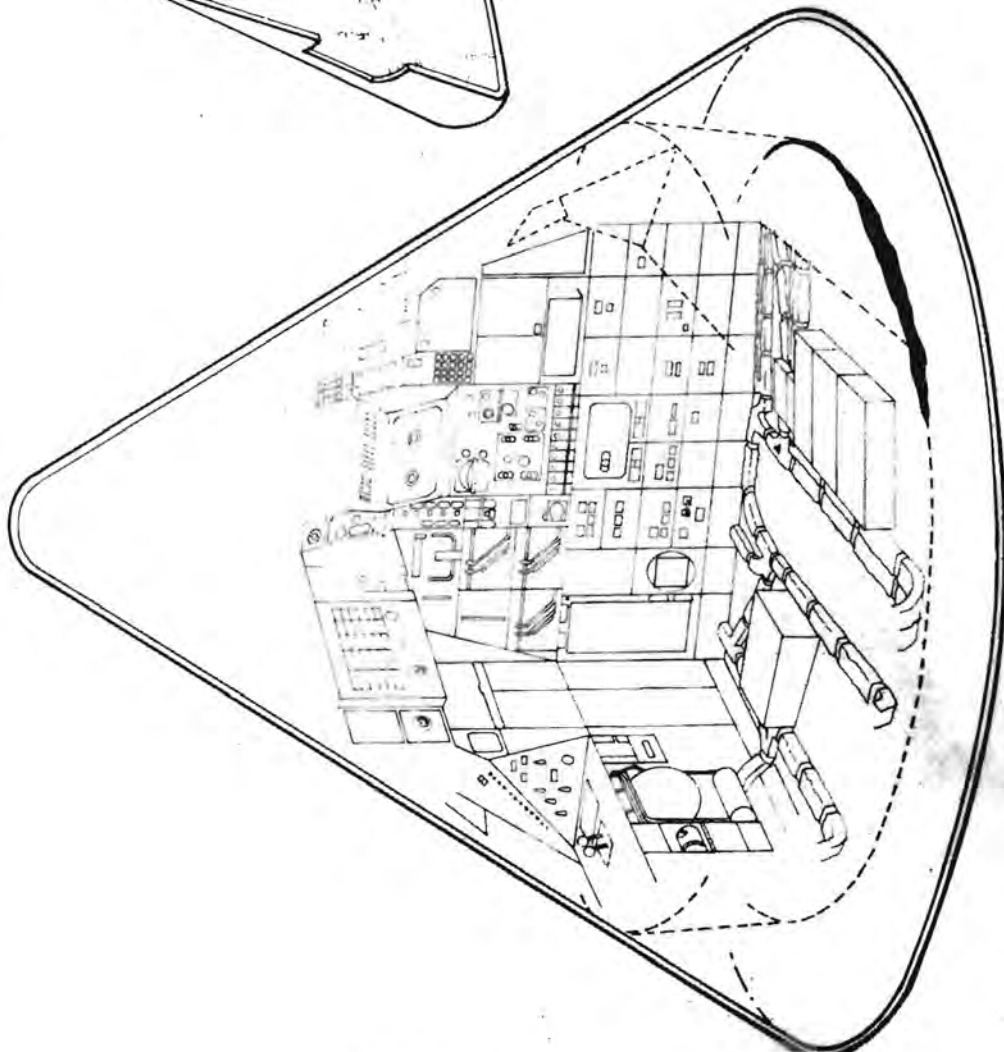




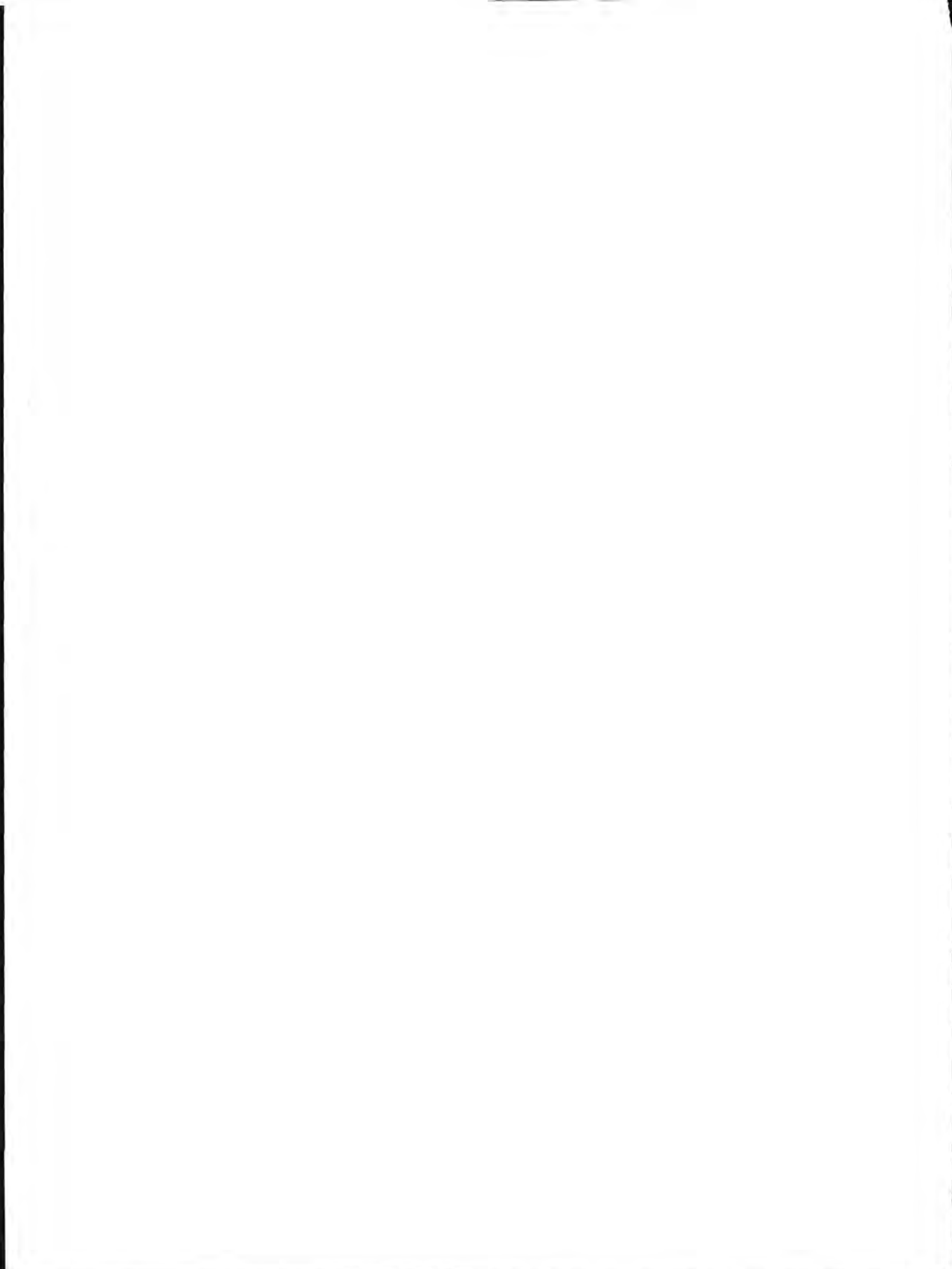
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FEB. 22, 1967
14

EXTREME RIGHT HAND CORNER ABOVE LOWER EQUIPMENT BAY AND RIGHT HAND EQUIPMENT BAY

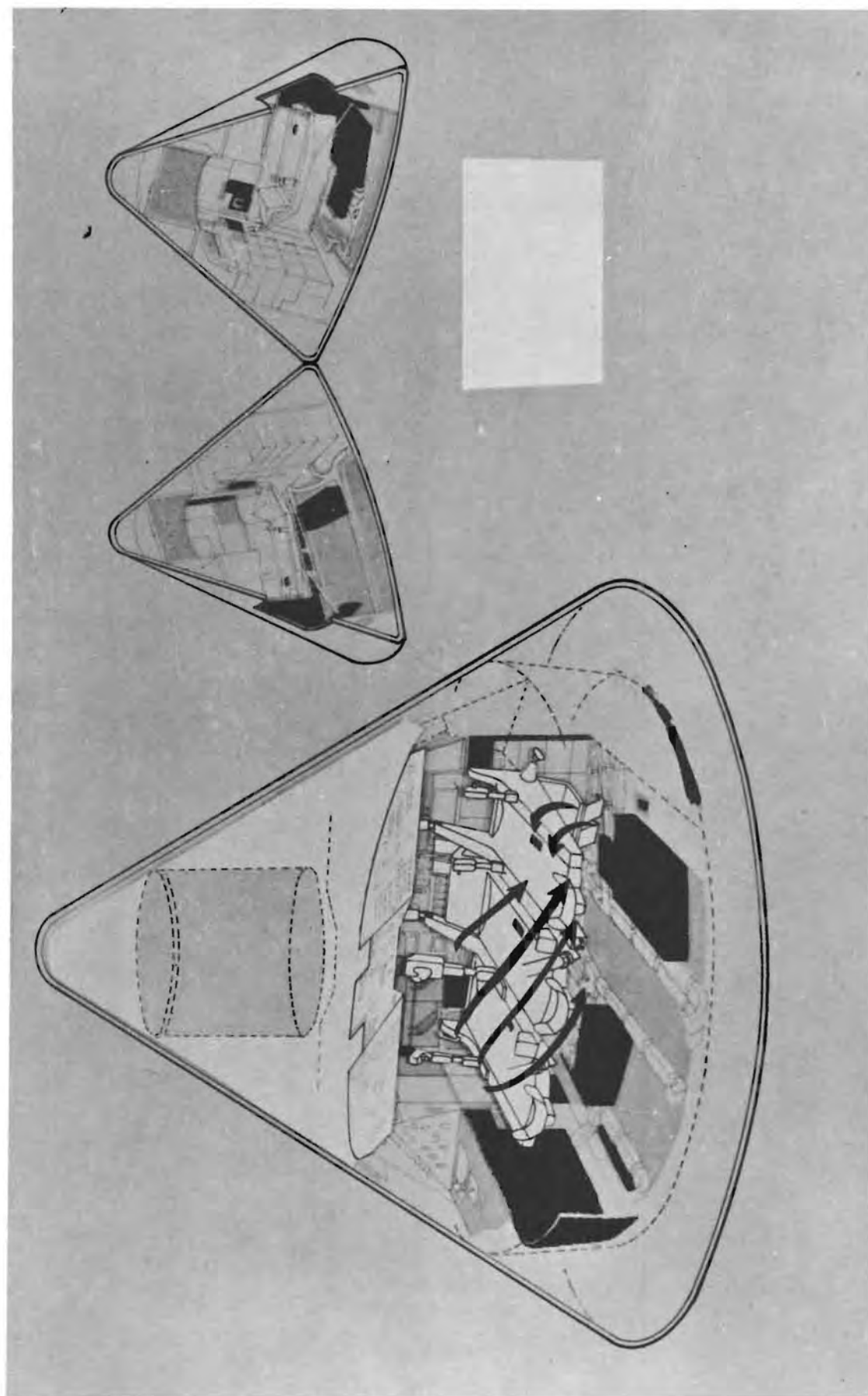
FIRST MAJOR FLOOR FRACTURE



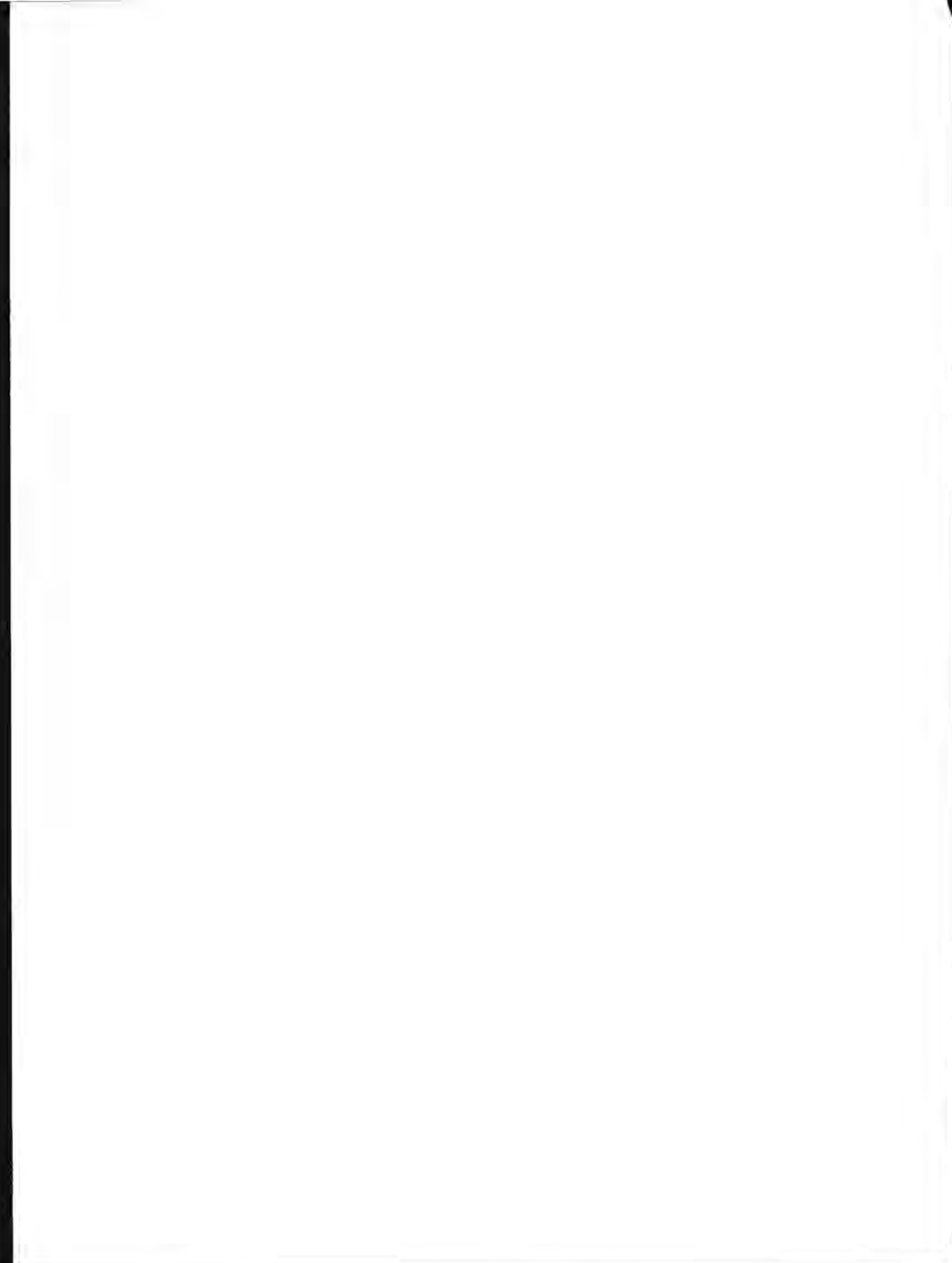
FIRST PRESSURE VESSEL FAILURE



FIRE OVER COUCHES 2nd FIRE PHASE



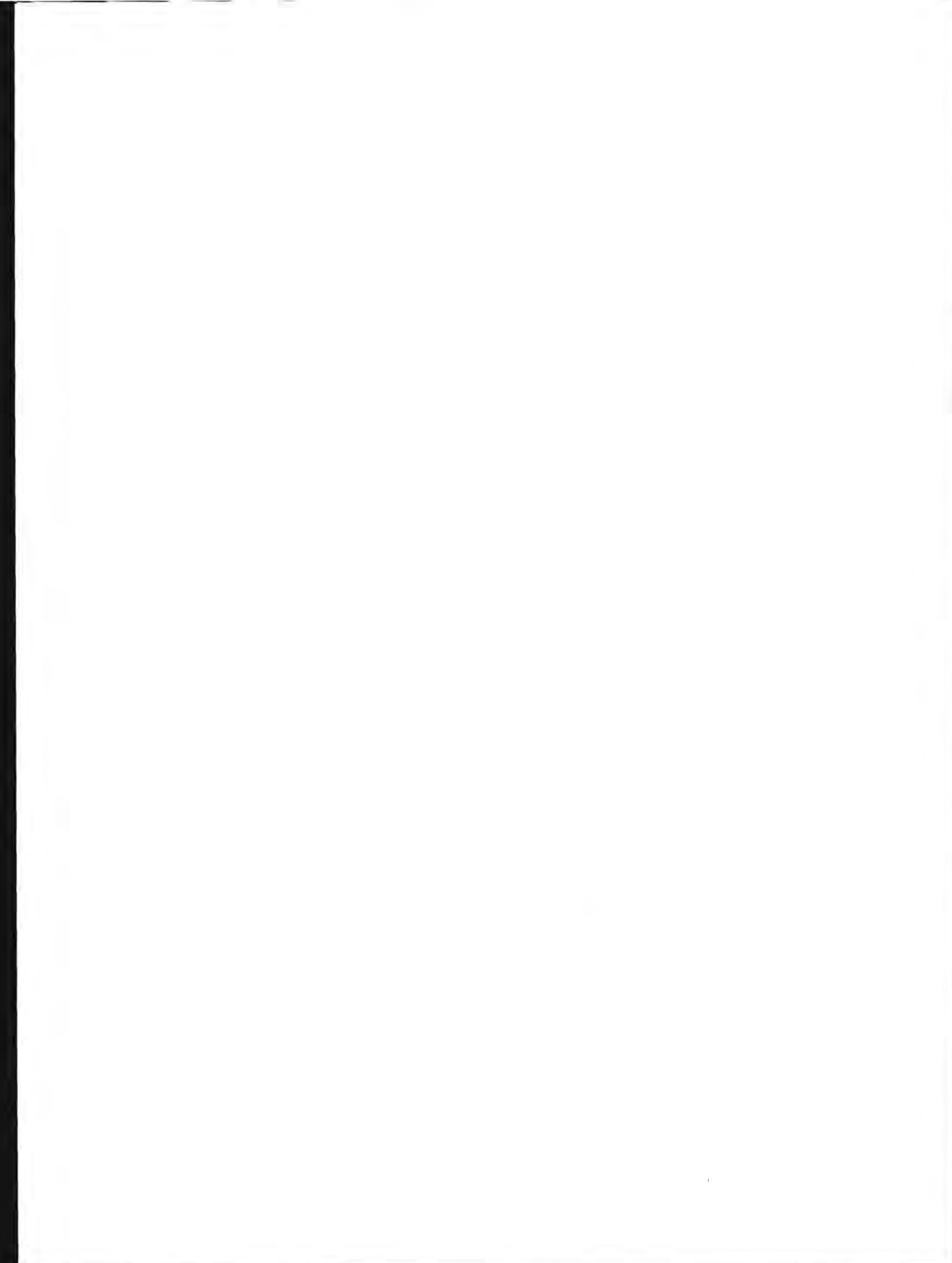
SECOND FIRE PHASE OVER COUCHES



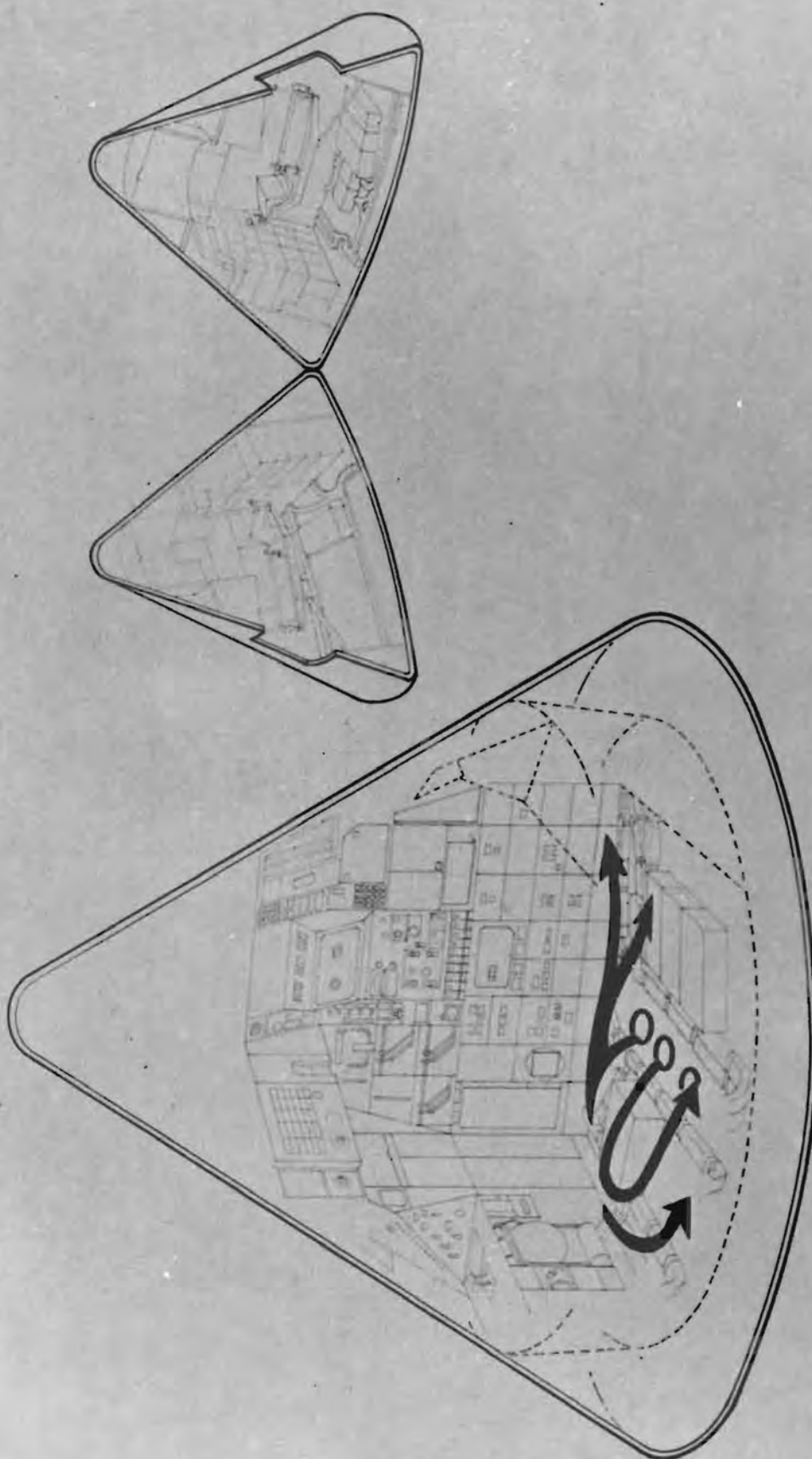


LEG REST CONTROL HANDLE

ENCLOSURE 5-14



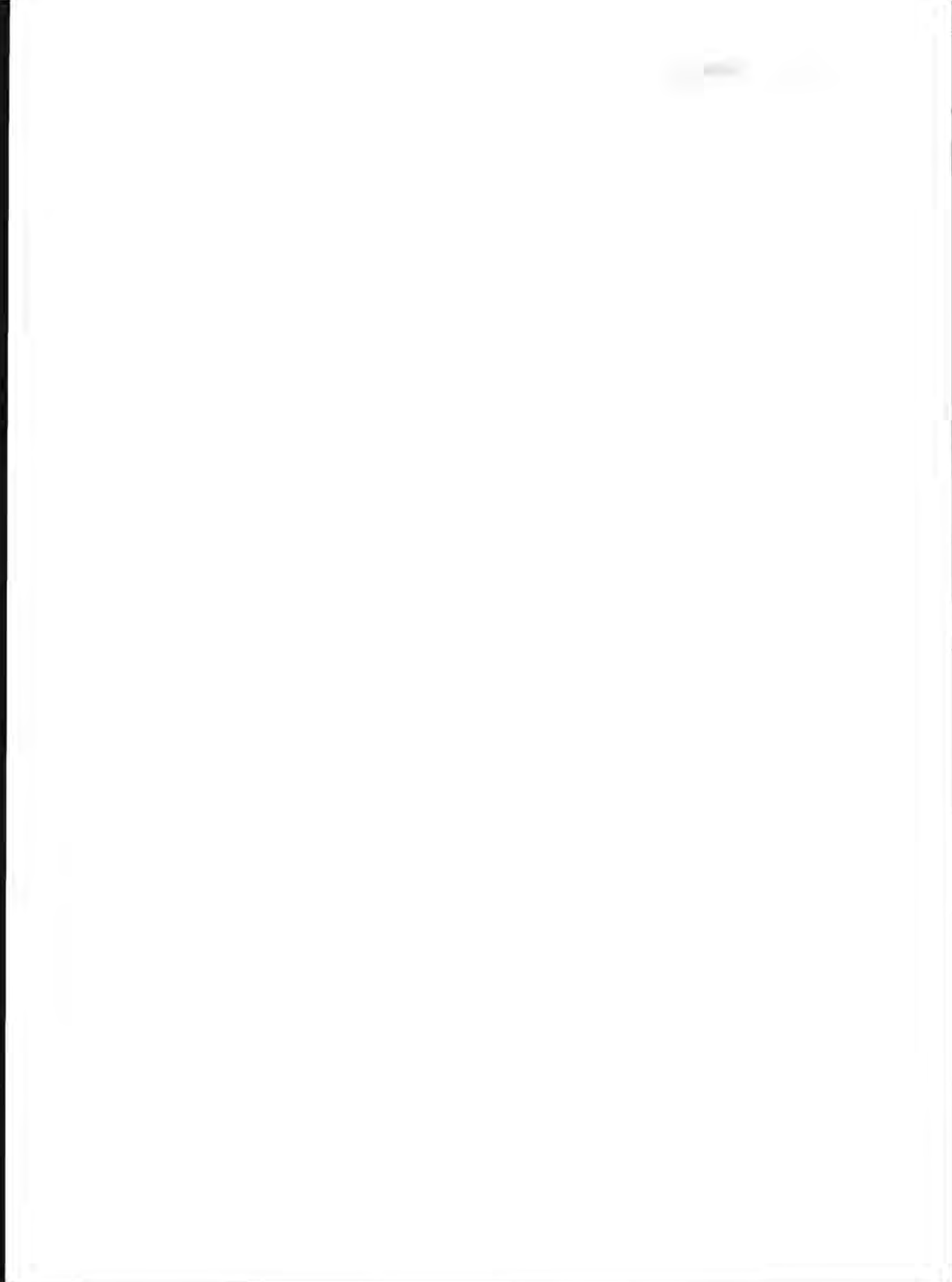
**FIRE ON C/M FLOOR
2nd FIRE PHASE**



SECOND PHASE OF FIRE -- ON THE FLOOR

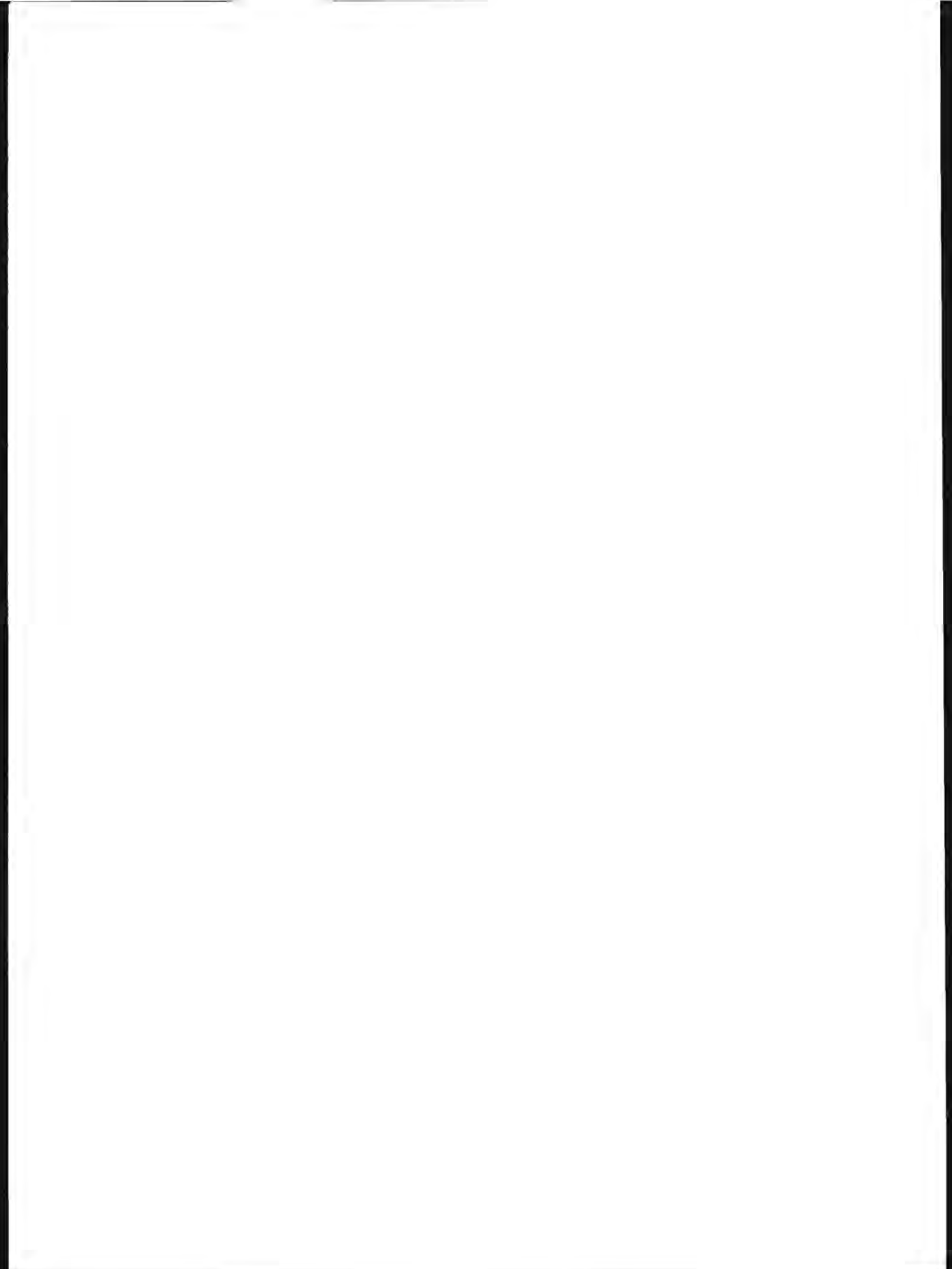


VIEW OF HELMET COVERS





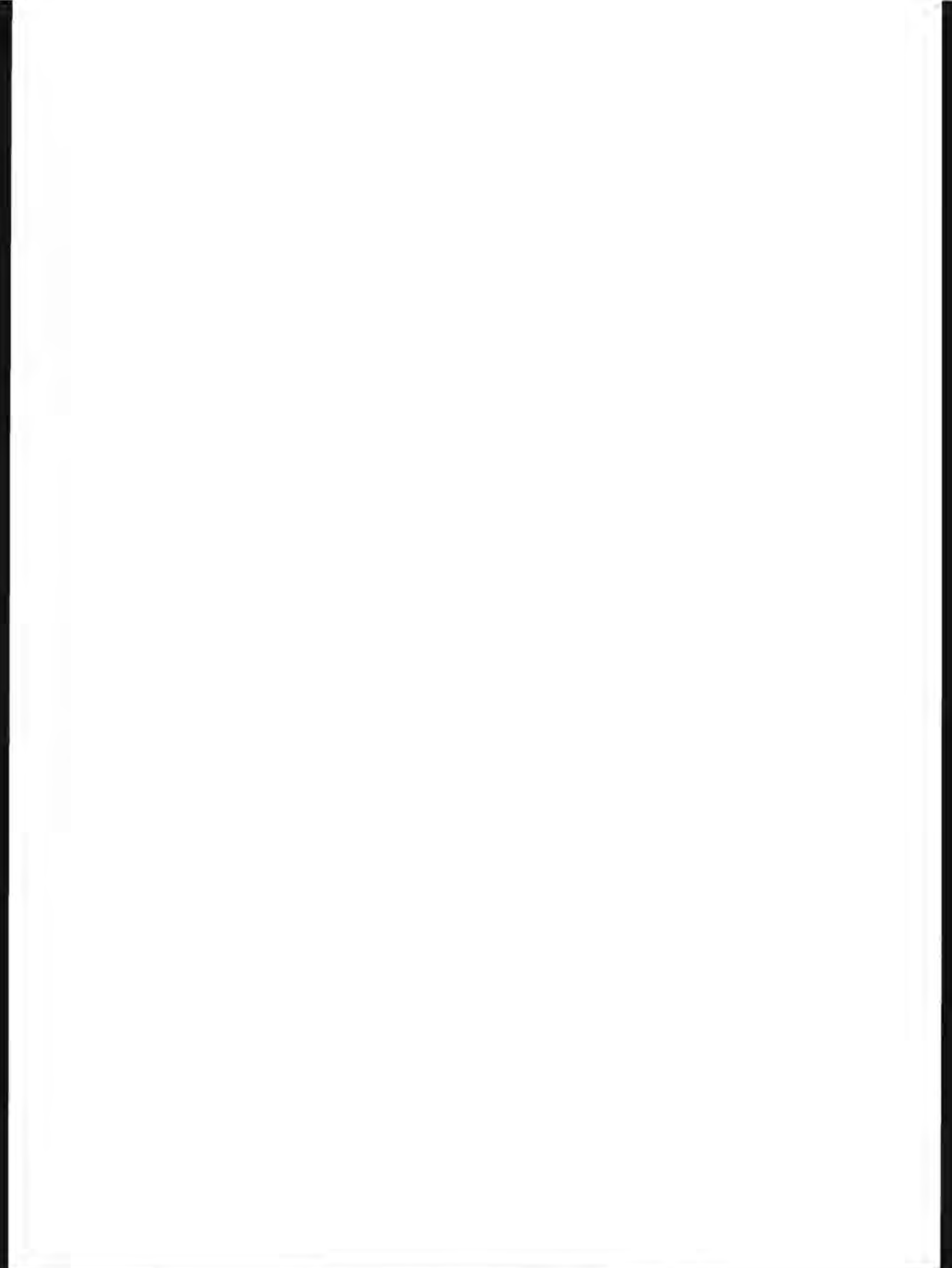
VIEW OF HELMET COVERS





VIEW OF FLOOR BELOW LOWER EQUIPMENT BAY

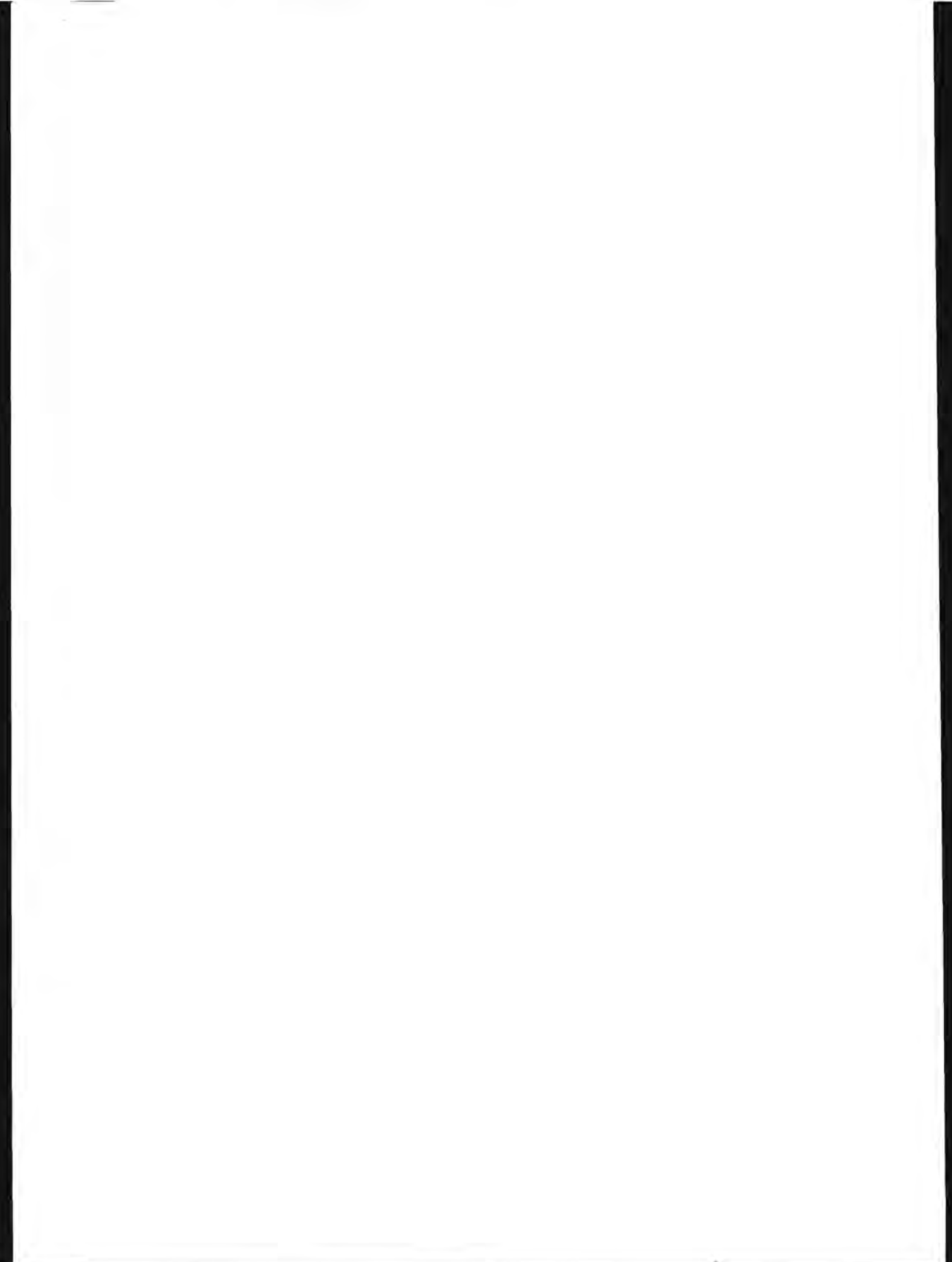
ENCLOSURE 5-18

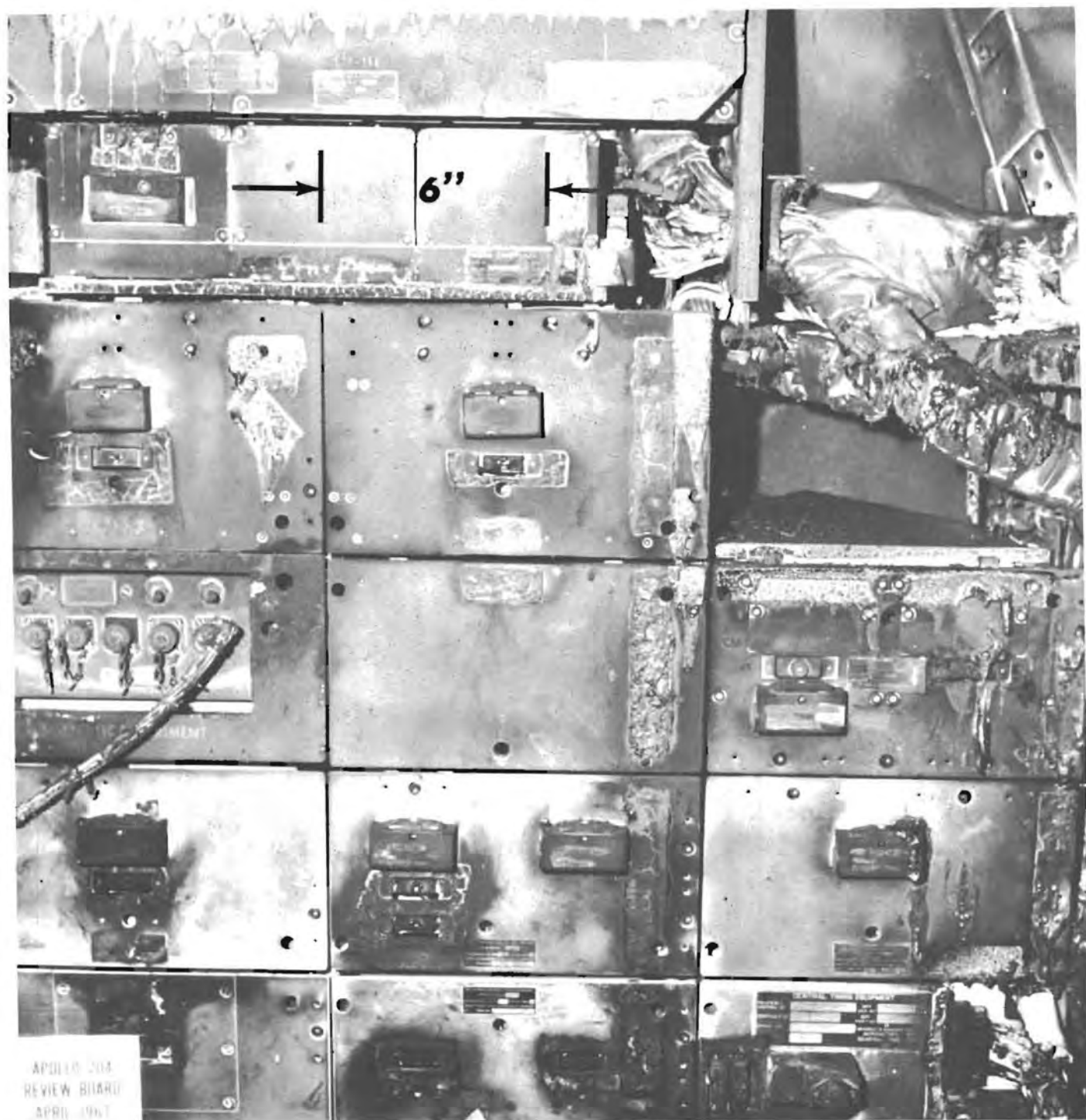


APOLLO
REVIEW B1
APRIL 15

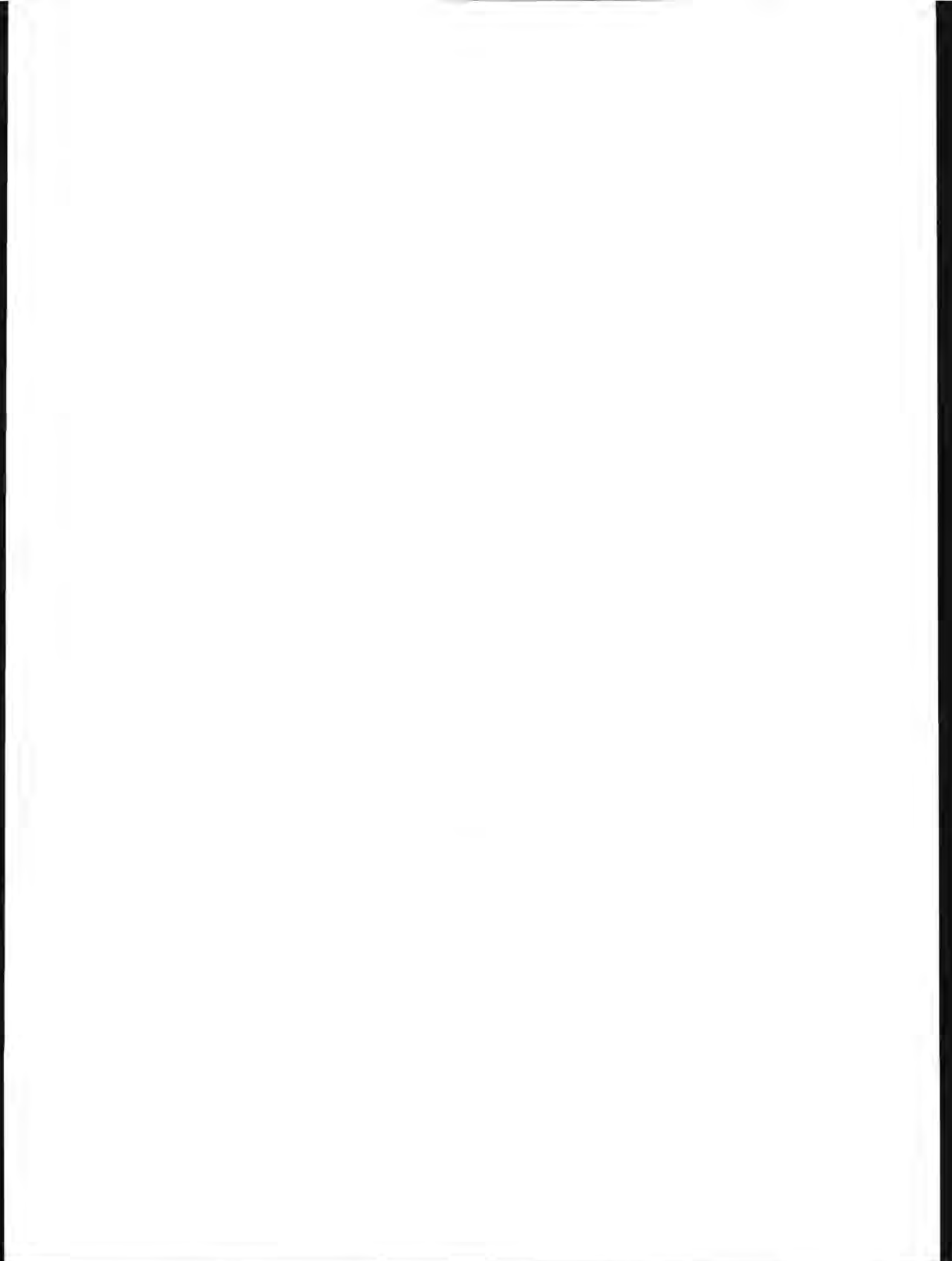


VIEW OF AFT BULKHEAD WIRING BELOW INVERTERS

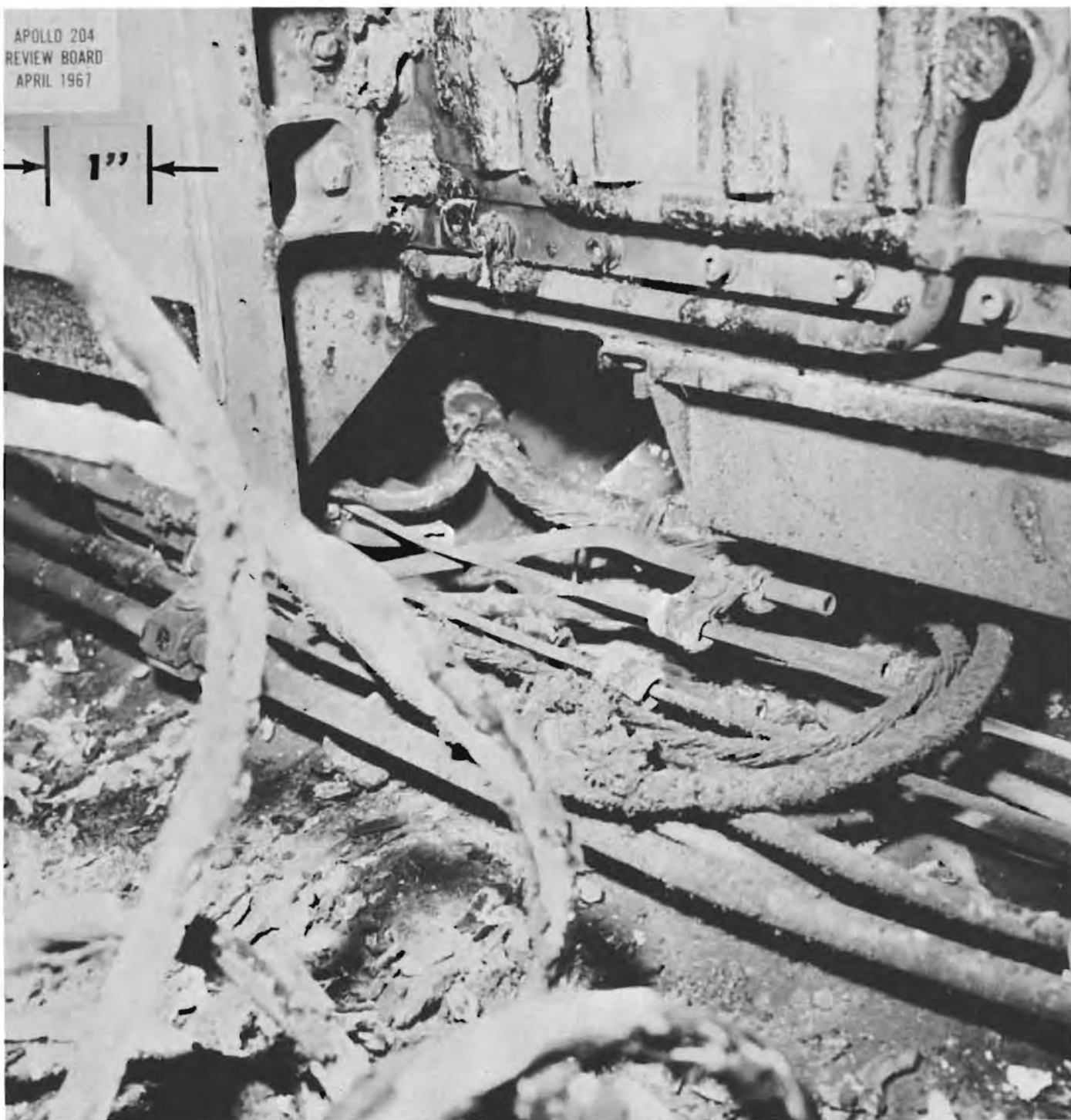
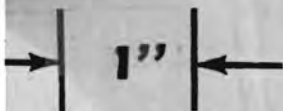




INSTRUMENTATION ABOVE INVERTERS



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APRIL 1967



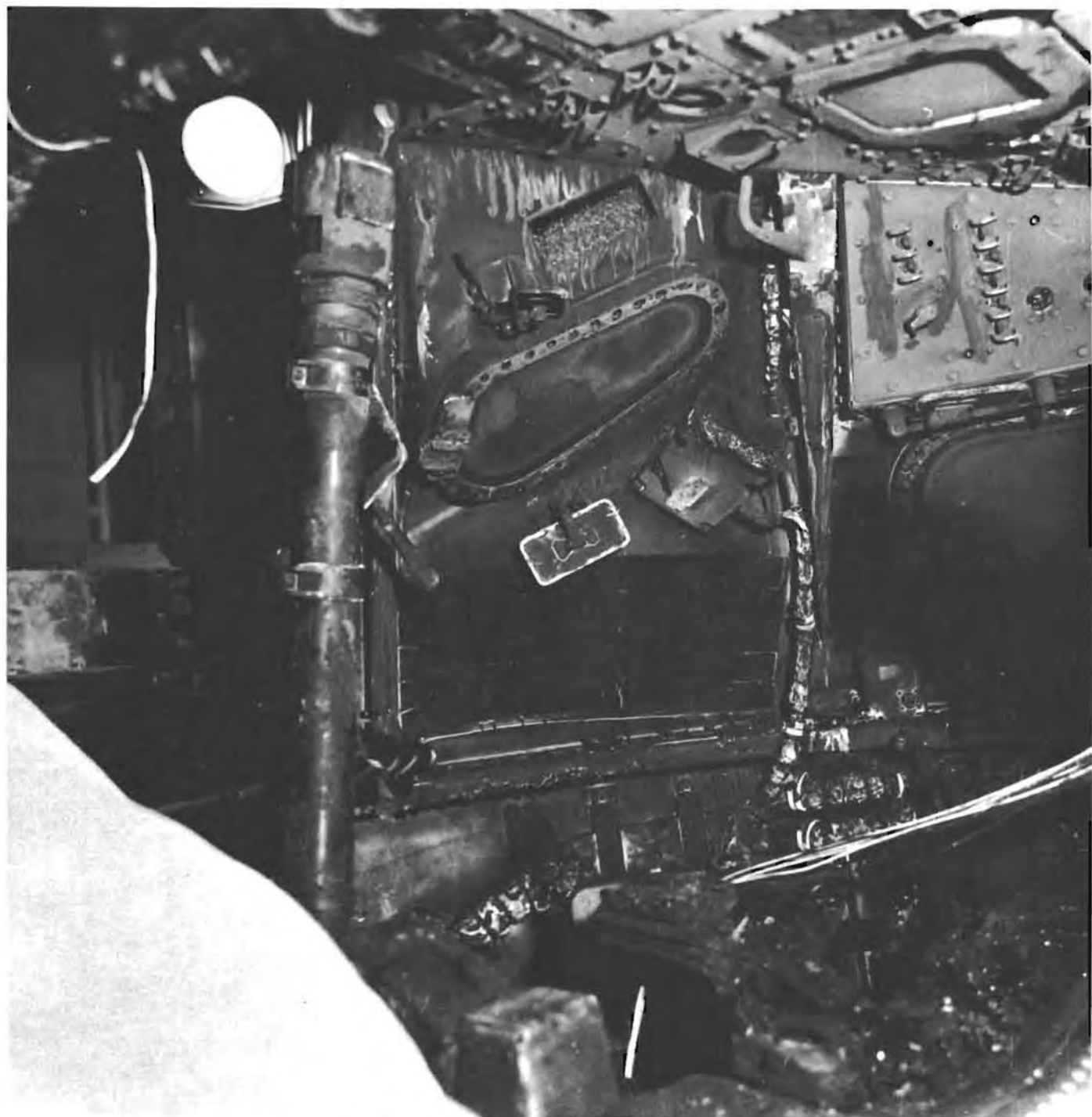
TUBING BELOW ENVIRONMENTAL CONTROL UNIT HEATING EXCHANGER

GAS CHROMATOGRAPH CABLE EXAMINATION

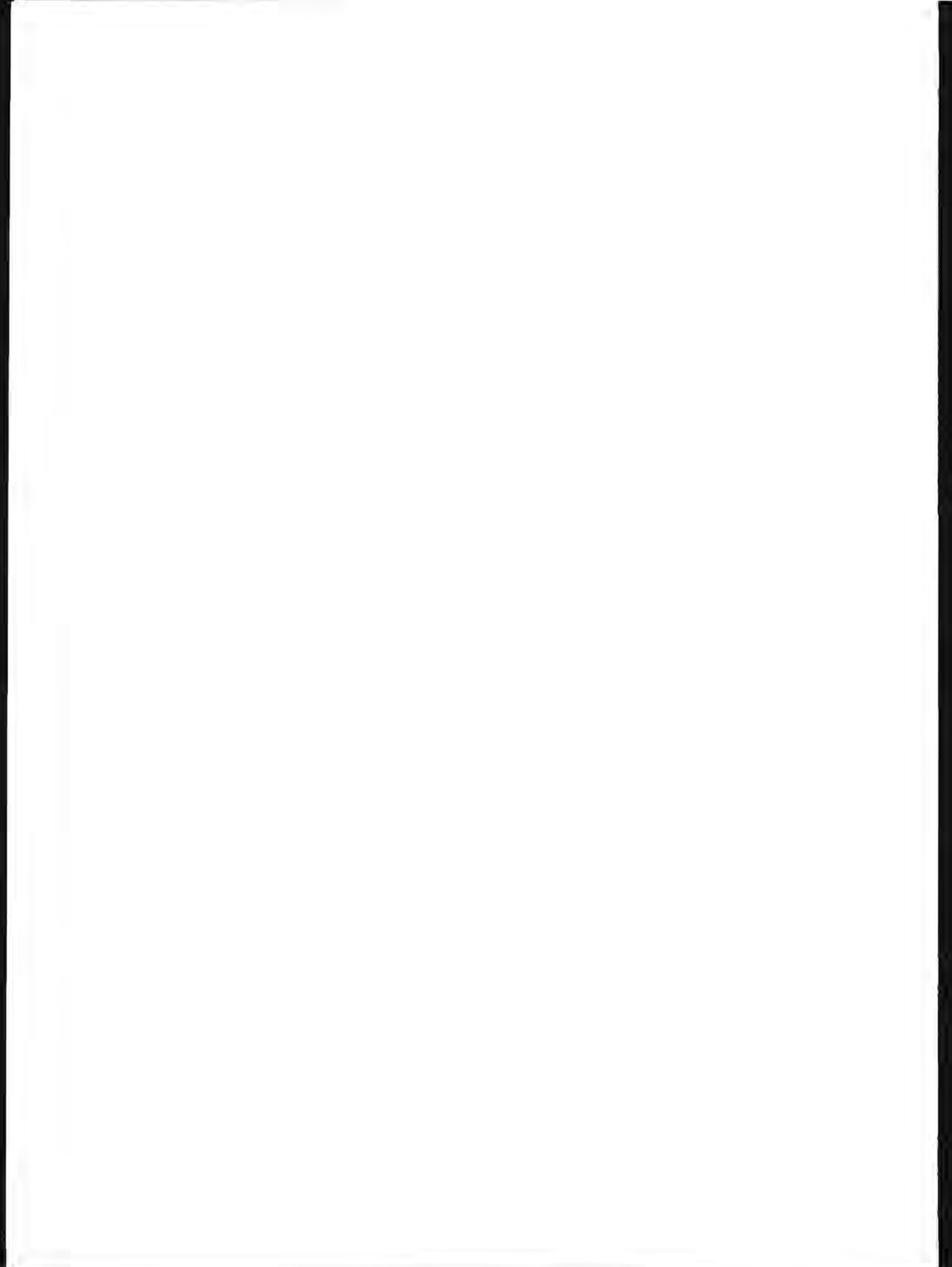
A. Disposition of Gas Chromatograph (GC Cable Harness and Connector)

Description	Condition	Analysis
<p>Observations on disposition of gas chromatograph cable harness and connector.</p>	<p>(1) Insulation from 117 V AC wires stuck to Pyro cable harness.</p> <p>(2) 117 V AC wire insulation broke through insulation (stuck to Pyro cable) as it fell to aft bulkhead.</p> <p>(3) Bare wires in cable harness match up with insulation residues adhering to Pyro cable.</p> <p>(4) Melted fiber glass tie wraps on cable harness in Channel "J" and Pyro cable, harness, and GC cable harness match up.</p> <p>(5) Set condition of GC cable harness near connector as it rested on aft bulkhead in a strained configuration.</p> <p>(6) GC connector was burned in 360° (spherical geometry).</p>	<p>As based upon analyses the GC cable harness was tied to the cable harness (J-185) below and in front the GC bay above Inverter No. 3. The connector was either lying on the floor of the GC Compartment or hanging in free space at left hand corner of the Pitch ECA. When the tie wrap on the cable harness burned through it fell to the floor.</p>

GAS CHROMATOGRAPH CABLE EXAMINATION		
B. Metallurgical Examination of Gas Chromatograph Cable Harness		
Description	Condition	Analysis
<p>(1) Samples of 117 V AC wire from a thermally unaffected zone in transverse and longitudinal mode.</p> <p>(2) As per item 1 except sampled in thermally degraded zone.</p>	<p>(1) Fine grain structure and twinning. A finite uniform nickel plate was observed.</p> <p>(2) Copper bead hollowed out. Extensive loss of copper from plated copper wire. Dendritic and gross grain structure with no twinning. Path of melting from wire to strand to bead clearly defined. Sharp grain structural zones between unaffected and affected heat zones. Tunneling and cavitation effects evident. Little alloying of nickel sheath and copper (only localized at nickel defects). Copper integrity below nickel sheath evident shows controlled melting phenomenon. Nickel plate was in a quench condition above tunnel.</p>	<p>(1) Wire in normally annealed condition. No alloying of nickel coating.</p> <p>(2) Highly concentrated and localized flame degraded Teflon and raised temperature to some value less than the melting point of copper between 600°C and 1000°C. Degradation of insulation allowed shorting of 117 V AC wires which provided further heat input driving the local temperature above the melting point of copper. Exclusive external or internal heating (arcing) cannot account for the metallurgical condition of wire but was a result of combined effects, one preceding the other, as evidenced by cavitation effects, sharp grain structural zoning, and unalloying of copper and nickel.</p>
(3) GC Connector	X-ray, resistance, and conductivity measurements were negative and showed no anomalies. No evidence of arcing was found on dielectric material.	Shorting of connector pins did not occur.

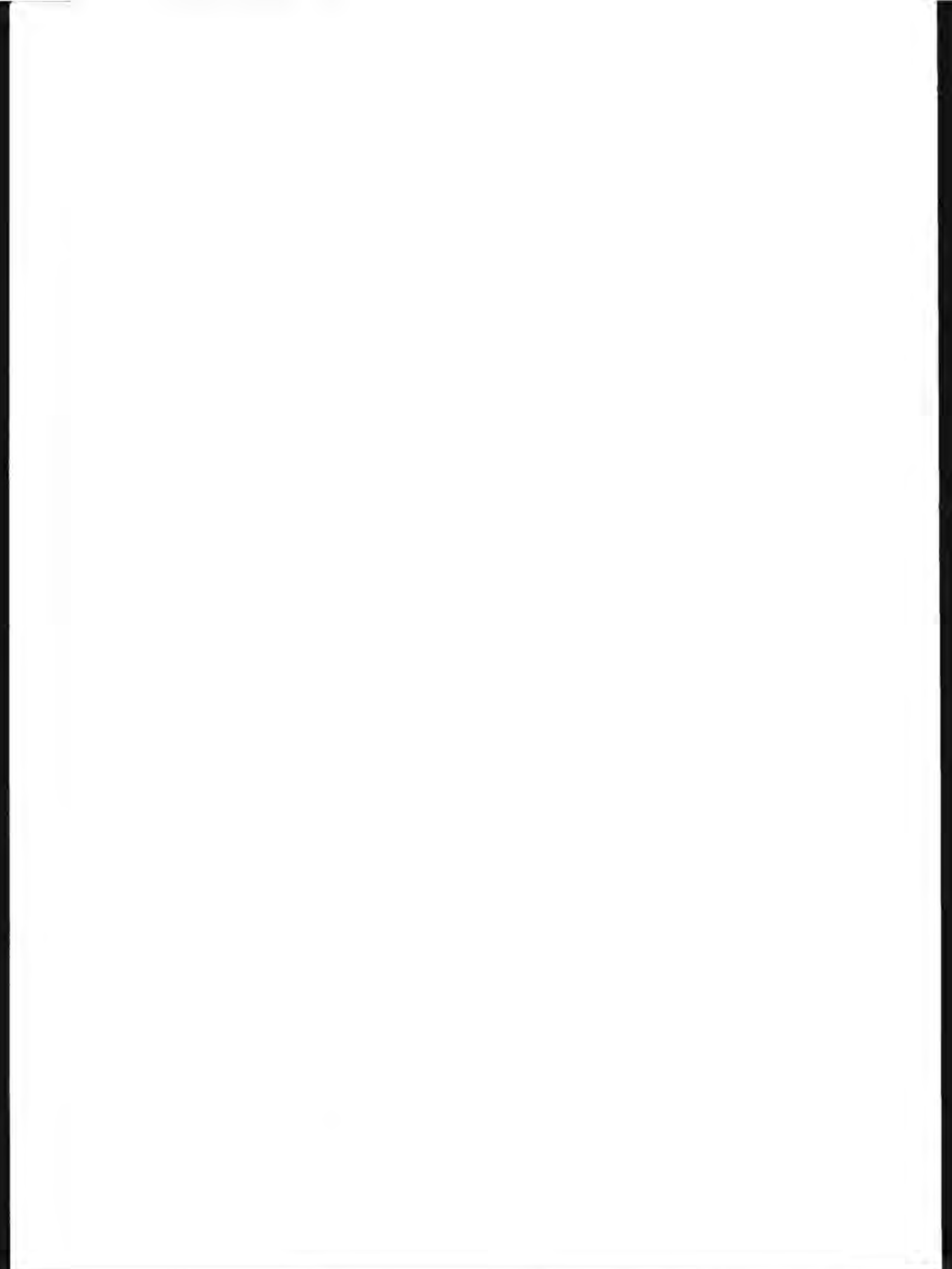


VIEW OF EXTREME LEFT SIDE FORWARD



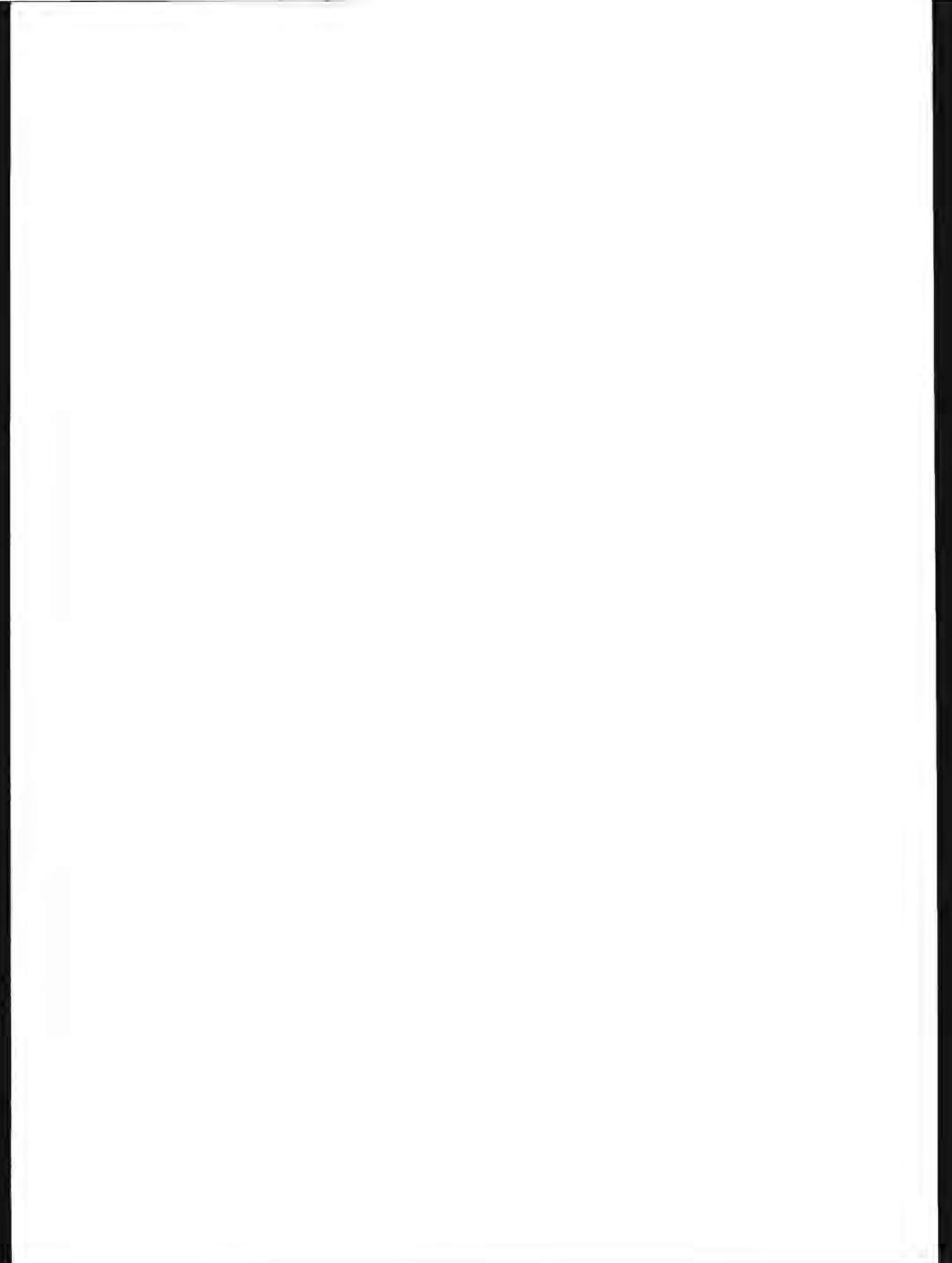


RIGHT HAND FORWARD EQUIPMENT BAY





PARTIAL VIEW OF RIGHT HAND EQUIPMENT BAY

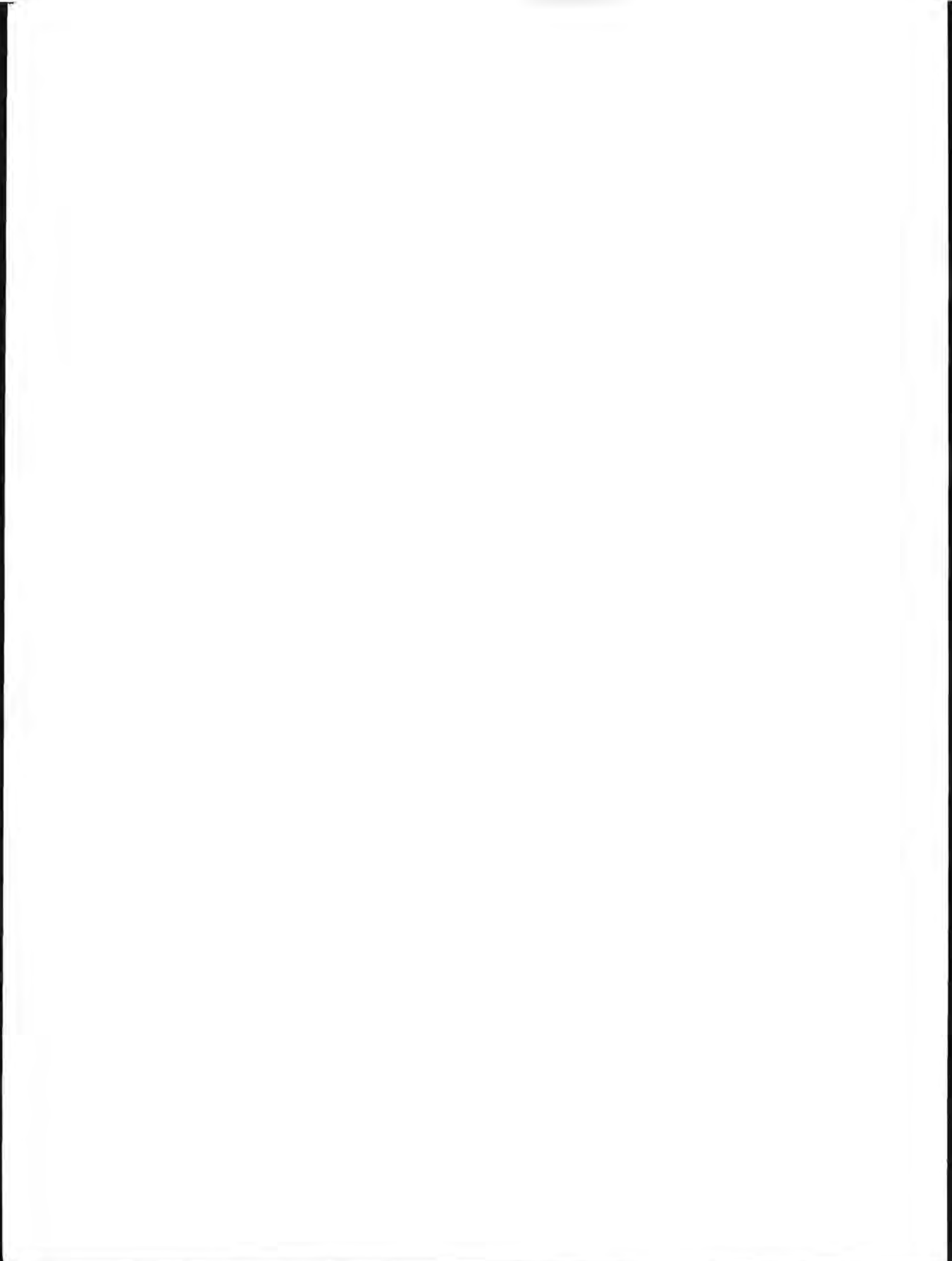


RIGHT HAND EQUIPMENT BAY	
Equipment and/or Panel	Conditions
DC Power Panel Instrument Circuit Breaker Panel Uprighting System Distributor Boxes	Sooted. Slight fire damage. Melted and partly burned plastic adhering to faces, tops, wires and back bulkhead.
Circuit Interruptors	Same as above. Wires at base show greater fire damage. Debris on base.
Earth Landing Sequencer	Sooted. Moderate fire damage on wires outside panels. Paint blistered on panel face.
Ground Support Equipment	Wire bundle compressed by cover panel, insulation split lengthwise after fire.
Others	Little soot. Slight fire damage. Some melted plastic. More damage in the + Z direction.

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GENERAL VIEW OF CABIN AREA INLET



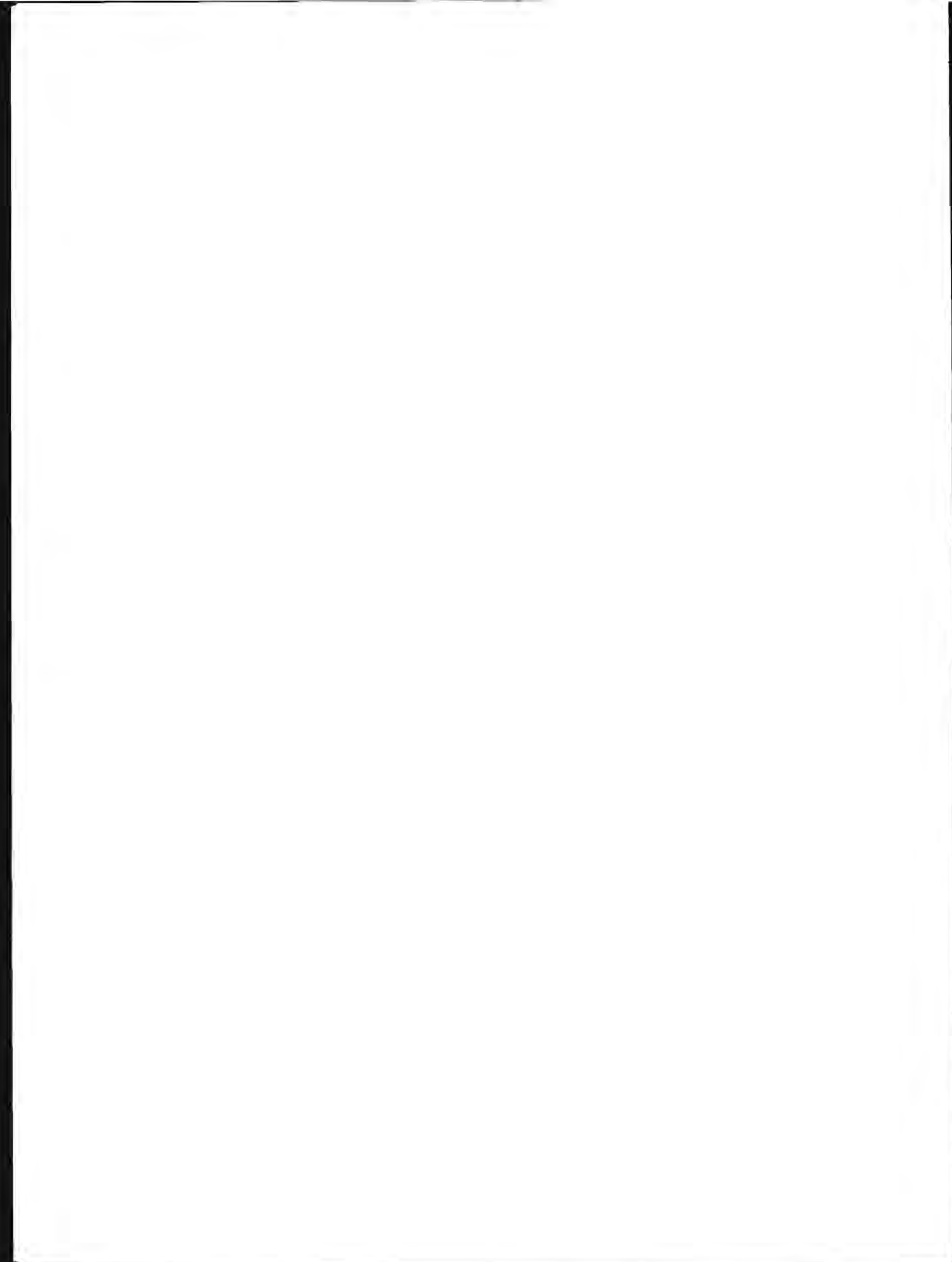
FORWARD EQUIPMENT BAYS

Equipment and/or Panel	Conditions
Cabin Intake Fan and Heat Exchanger Area	Heavily sooted, Burned plastic, Moderate fire damage.
Drinking Water Fountain	Panel on bottom burned through. Heavy soot. Burned plastic inside.
Loose Equipment Storage	Heavy soot.
Suit Loop Outlets	Hot jet burn. Heavy soot.
Access Tunnel Above Suit Loop Outlets	Hot jet burn. Velcro slightly melted.
Tunnel	Slight fire damage.
Escape Hatch	Melted nylon on intake vent fan. Dripped plastic on wire. Soot.
Right Hand Bay	Minimal fire damage.

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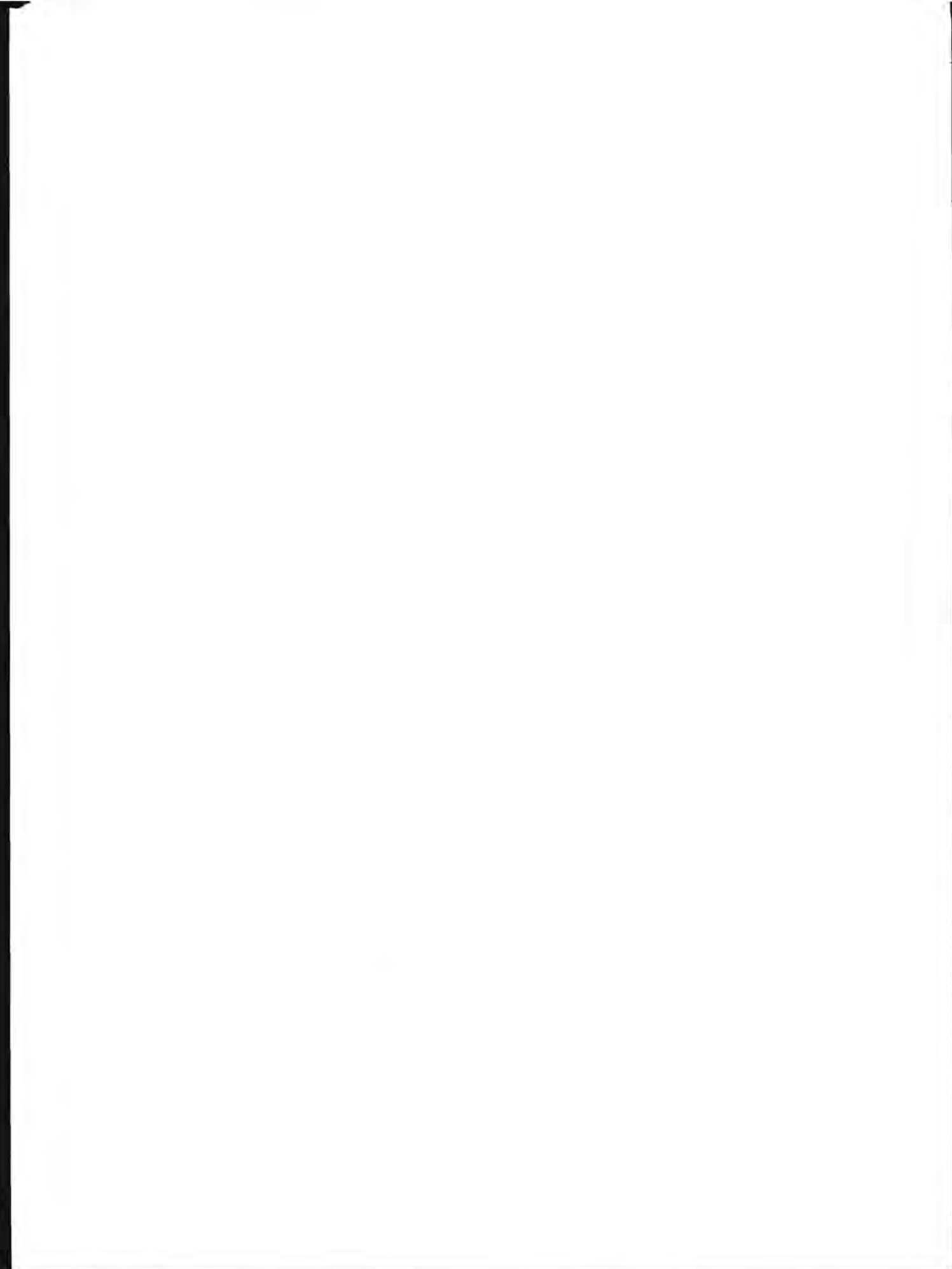


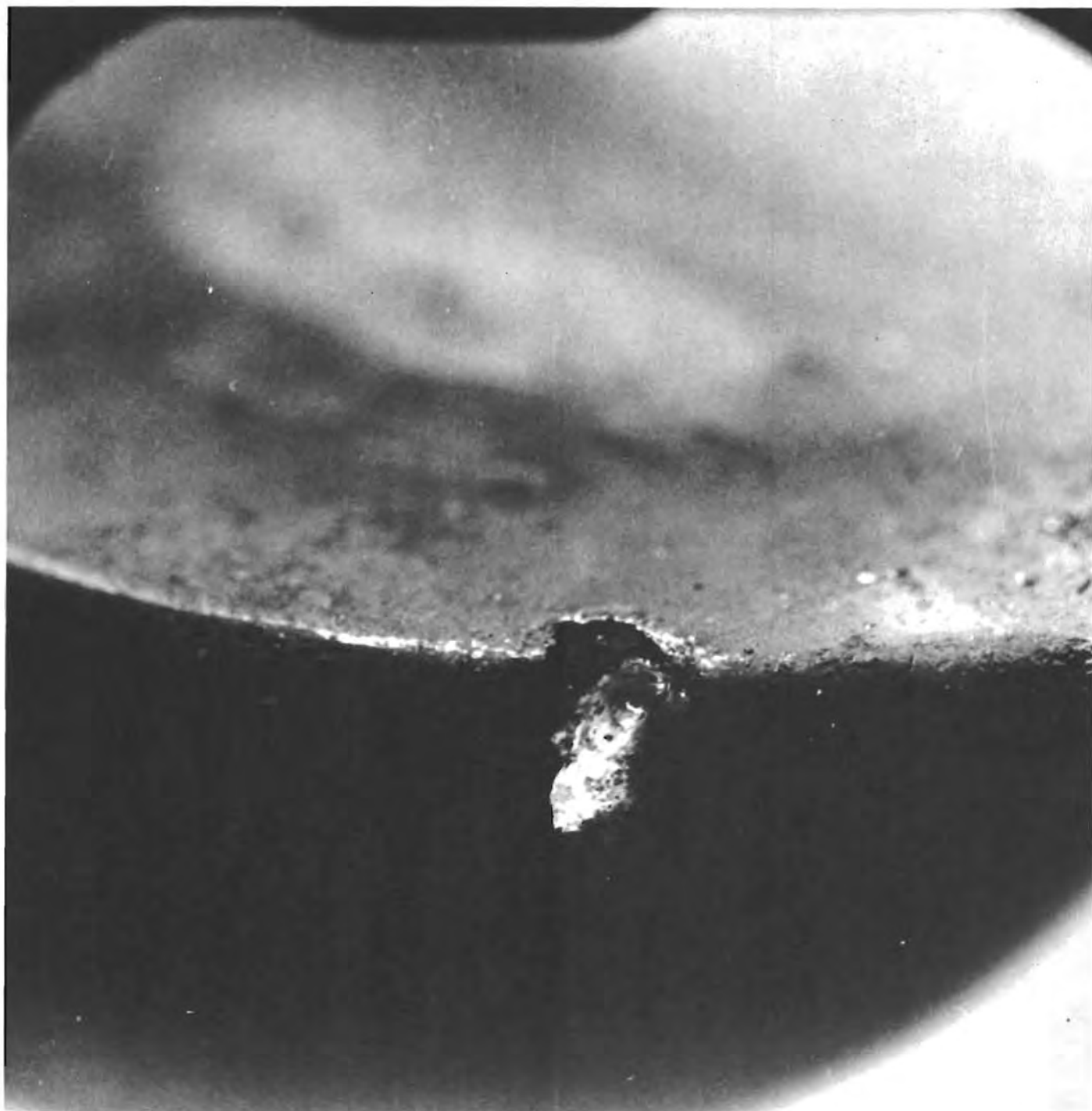
RIGHT HAND SECTION OF LOWER EQUIPMENT BAY





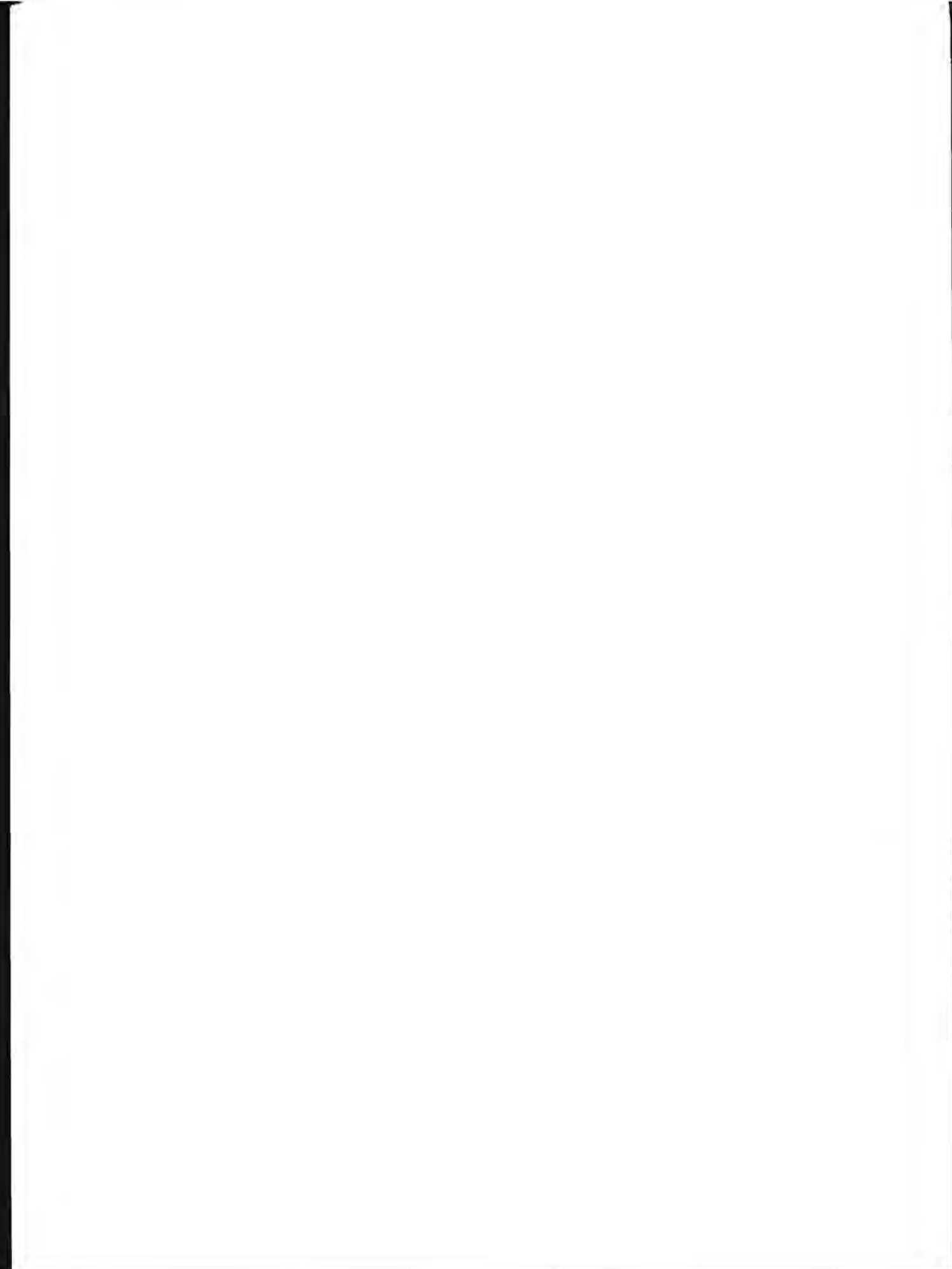
LOWER LEFT HAND SECTION OF LOWER EQUIPMENT BAY





VIEW OF ARC ON PANEL 109

ENCLOSURE 5-31A



LOWER EQUIPMENT BAY, + X HALF

Equipment and/or Panel	Conditions
Food (Panel A)	Blistered paint. Warped panel.
Food (Panels B, C, D, E)	Melted metal on doors, more severe on C and E. Melted Velcro inside. Fire damage to insulation on glycol line at rear.
Instrument Storage Unit	Fire damage to foam insulation, worse on outside and left, and to rubber on instruments. Bay relatively clean.
Guidance and Navigation Optics	Burned gasket, blistered paint, melted plastic on left, slightly melted on right.
Guidance and Navigation Instrument Computer	Hot jet effect from lower left corner. Melted potting on connectors. Melted plastic, peeled tape, corrosion inside. No apparent fire damage in bay, melted plastic on wire bundle upper right.
Power Servo Amplifiers	Plotting melted and dripped plastic on left hand amplifiers. No apparent fire damage to bay.
Coupling Display Units	Erosion of insulation on wire pairs.
Altitude Gyro Accelerometer Package. Altitude Gyro Accelerometer Bay. Navigation Display and Keyboard.	Heavy soot. Melted potting. Fire damage to insulation on glycol line back of Accelerometer Bay.
Data Storage Equipment Signal Conditioner	Heavy soot. Slightly melted Velcro.

LOWER EQUIPMENT BAY, -X HALF (CONT)	
Equipment and/or Panel	Conditions
In-flight Recorder Scientific Package A Gas Chromatograph Bay	Moderate Soot. Burned and bare wires in front of panels. Fire damage to Teflon wrap on wire bundle at right and top, wire harness squeezed. Fire damage to insulation on water/glycol line at right rear. Burned Teflon overlay in bottom plate cutout. Dried condensate streamers on pressure vessel.
Altitude gyro Accelerometer display yaw, pitch, roll auxiliary electronic control assemblies	Burned paint on face. Melted potting on connectors (More severe on left). Melted plastic on panels. Broken connector lips on assemblies with soot on gaskets and fractured lip. Slight fire penetration behind left face of panels. Moderate soot.
Apollo Guidance Computer Scientific B Package. Unified S-Band Equipment Up Data Link	Blistered and burned paint on face. Slight fire damage to wire bundle in Computer bay. Moderate soot.
Pulse Code Modulation (1 and 2) Quality Telemetry Recorder	Heavy soot. Decreasing fire patterns left to right. Melted Velcro on faces.
VHF - AM and FM	Heavy soot. Melted potting on side connectors. Melted Velcro on faces.
VHF Multiplexer	Melted Velcro on faces.
S-Band	Melted plastic adhering to face. Burned blow-hole in potting behind face plate. Melted potting on connectors. Bare wires on top connector.
C-Band	Upward flame streak on face.
Data Wiring	Slightly melted Velcro
Pre-Modulation Processor	Melted Velcro. Melted plastic adhering to face. Melted potting on connector. Bare wire on right side connector. Light soot in bay.
Audio Center	Melted Velcro. Face sooted. Melted plastic adhering to face. Cracked Hughes connector, with bare wires. Melted potting. Light soot in bay.

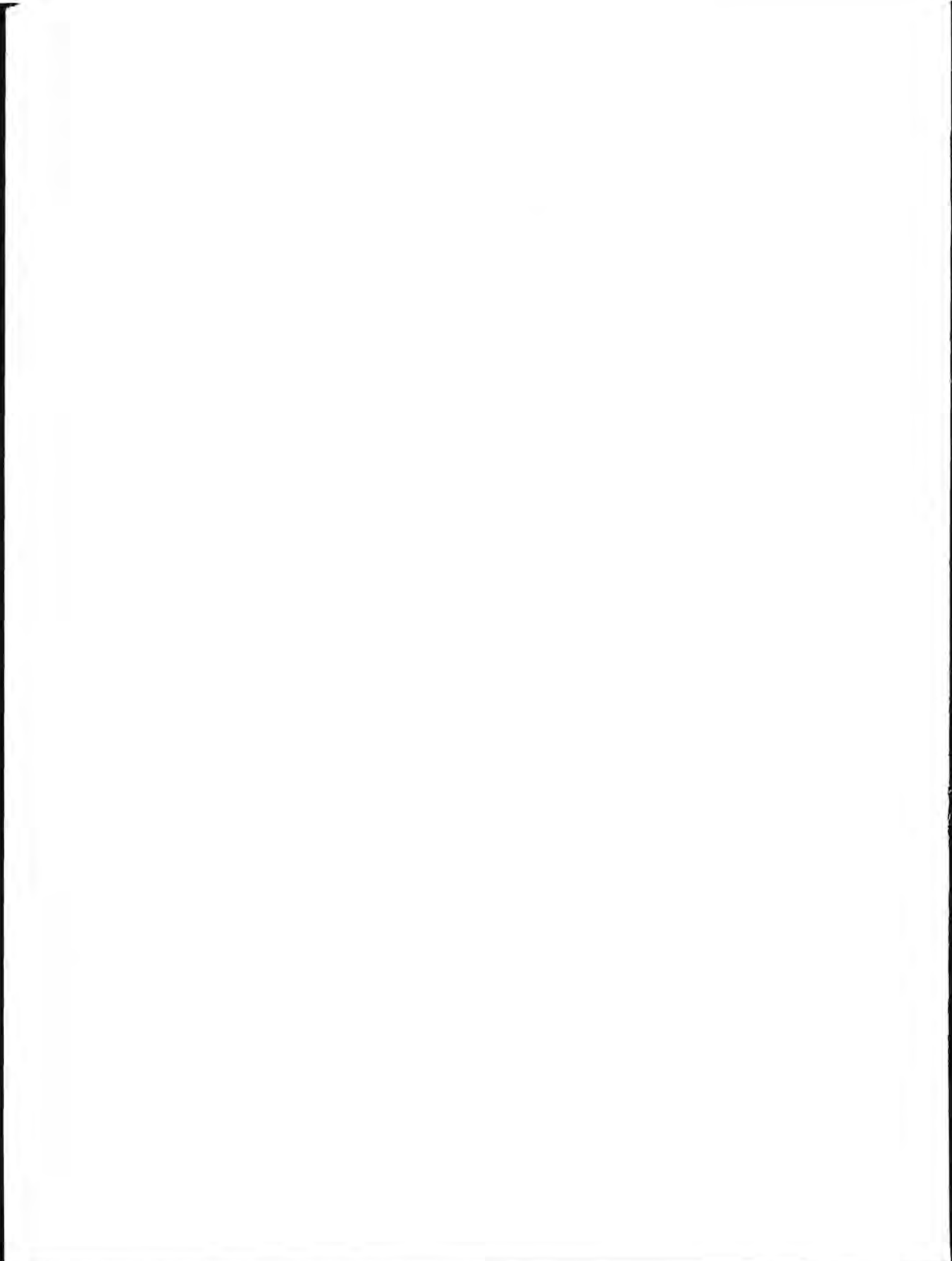
LOWER EQUIPMENT BAY, -X HALF (CONT)

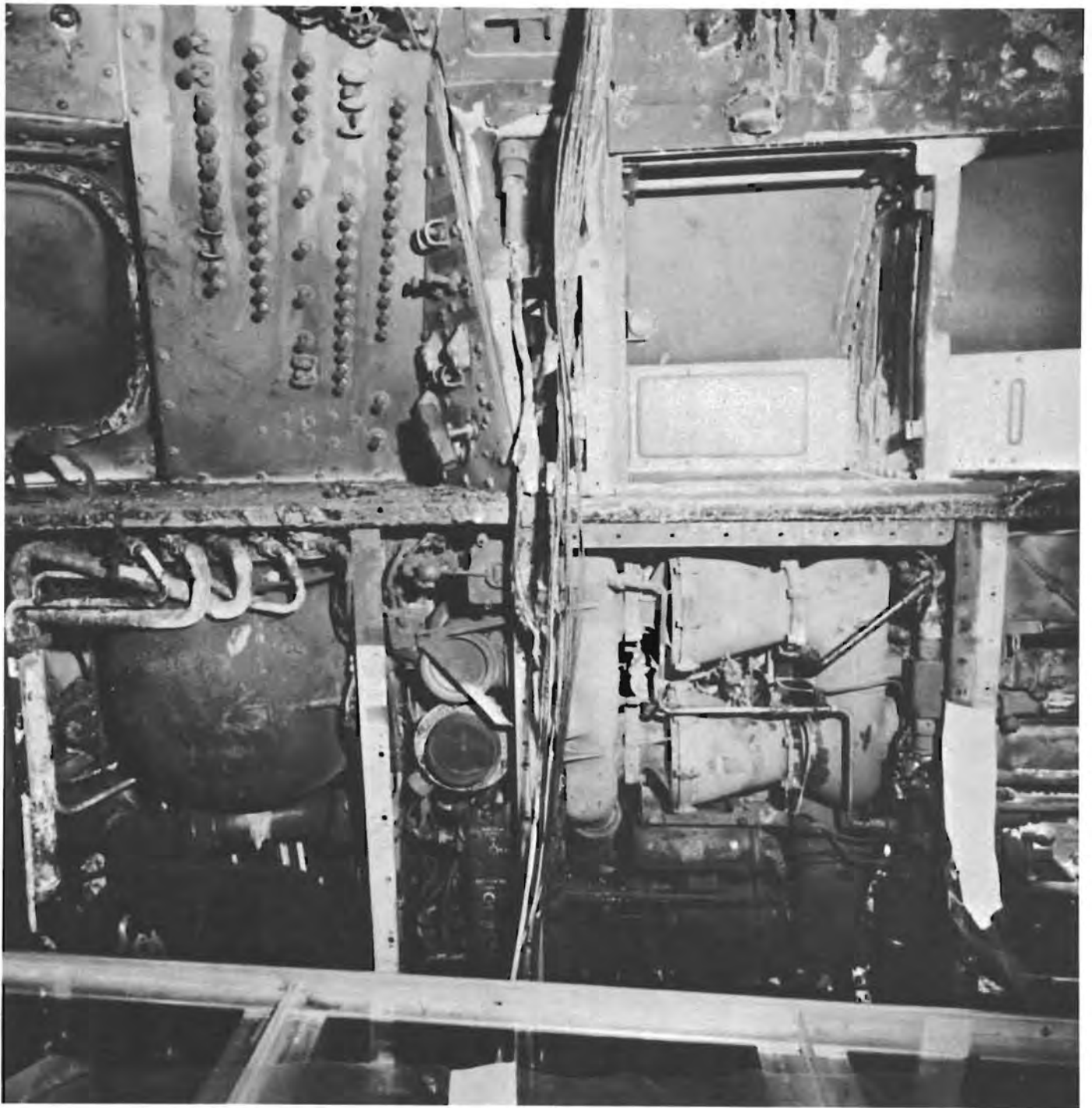
Equipment and/or Panel	Conditions
Central Timing	Melted Velcro. Melted potting and bare wire on lower left connector. Light soot in bay.
Connector C-15-1A-52	Severe fire damage. Panels heavily sooted. Melted chafing guard. Evidence of arc in lower right hand corner. Nylon chafing guard in cover plate 3/16 in. from arced spot. Burned wired in harness at bottom. Squeezed wire bundle against Inverter No. 3.
Inverter No. 3	Buckled bottom and face plates. Heavy soot.
Batteries A, B, C	Severe fire damage. Slight separation of outer container. No penetration to electrolyte.
Inverter and Battery Compartment	Sooted. Debris. Little fire damage. Exposed wires in slot above B battery burned bare and fused. Slight fire damage to insulation of glycol line back of Inverter No. 1. Melted and burned hole in pressure vessel.

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LEFT HAND FORWARD EQUIPMENT BAY



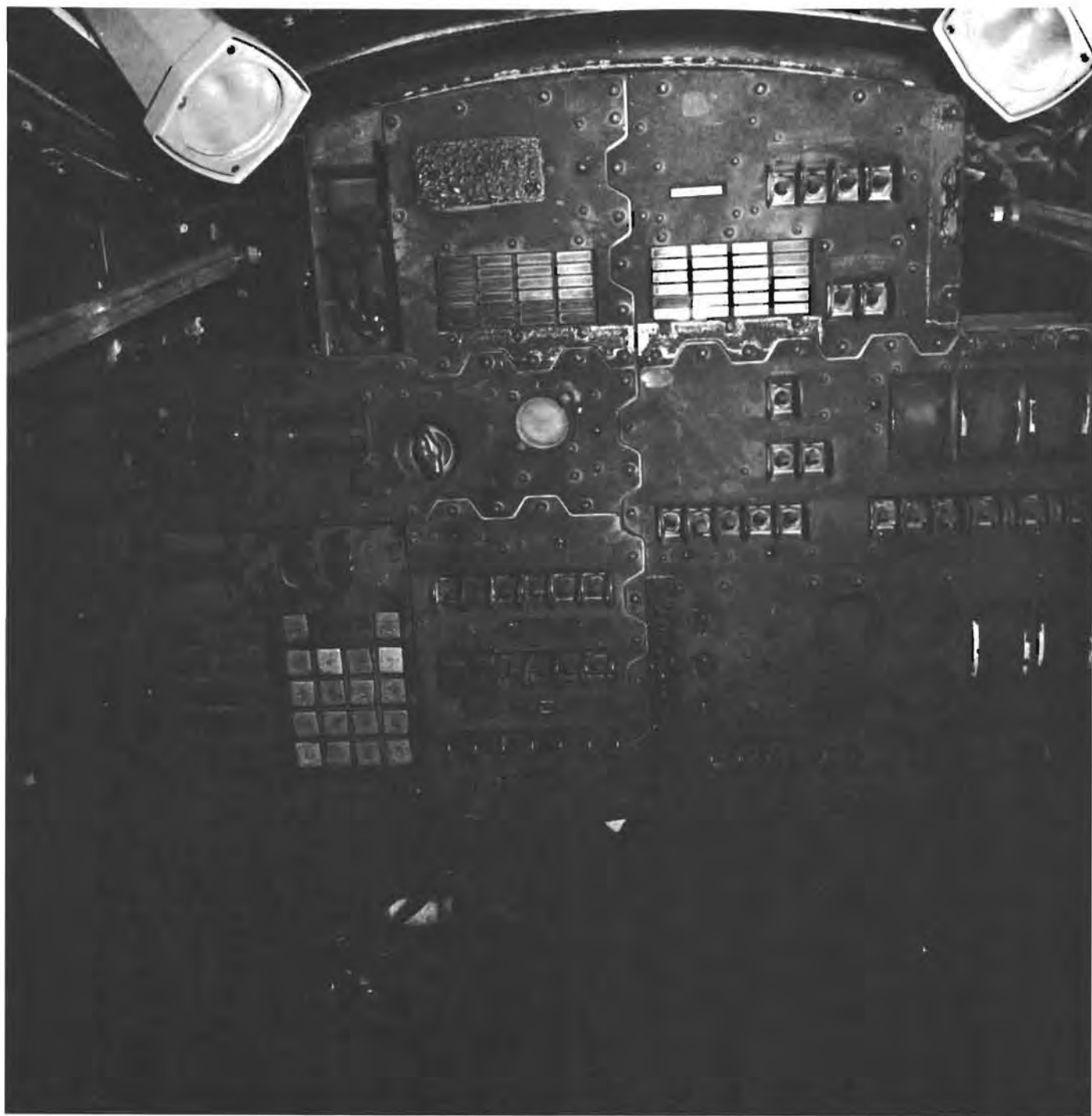


VIEW OF ENVIRONMENTAL CONTROL UNIT

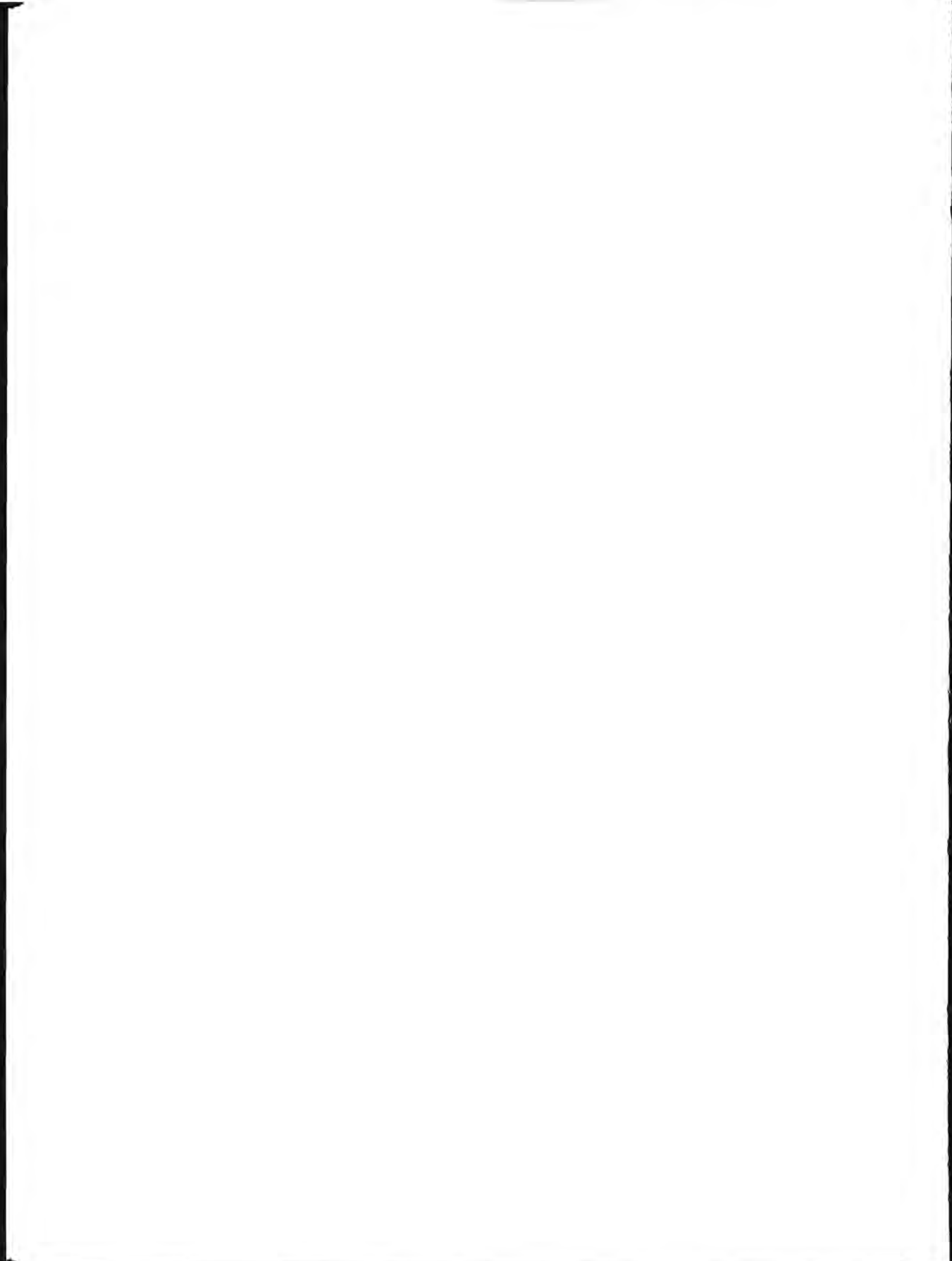
LEFT HAND EQUIPMENT BAY

Equipment and/or Panel	Conditions
Oxygen Panel	Burned Velcro on face. Melted cabin emergency valve on face. Severe fire damage, worse on inside. Potting blown out of solenoid. No apparent tube failure.
Water Panel	Very severe fire damage inside. Tubing burned away. Melted plastic adhering to face and tubing. Torch-like hole burned in pressure vessel wall on back of bay. Bare wires and wires burned away. Severe melting of wire harnesses. Massive hole burned in pressure vessel in aft bulkhead, extending to CO ₂ Absorber Bay. Right hand bay bulkhead severely burned and melted. Molten ingot on floor covering wire cables leading to CO ₂ Absorber Bay.
CO ₂ Absorber	Severe heat and fire damage, melted and burned across bottom of door. Melted plastic adhering to hinge. Compartment A showed low order explosion door blown open, LiOH spilled, felt pads missing, housing distorted, activated carbon present in rear. Compartment B had hole burned through lower right side and bottom, LiOH spilled and partly fused, no front felt pad. Very severe fire damage in lower section of compartment, burned, melted and fused wiring, burned and melted gas transfer lines, water line blown open. Massive hole burned in floor. Left hand wall severely burned at bottom, molten ingots present.
Environmental Control Unit	Insulation completely burned on front of heat exchanger, decreasing fire damage toward rear and left. Tubing on floor separated and melted. Condensate streaks on back wall. Moderate fire damage to floor.
Surge Tanks and One-lb. Oxygen Bottle Area	Hot jet effect upper rear right-hand corner. Heavy soot. Moderate heat damage to insulation on front tubing. Melted plastic adhering to components in area.
Surge Tank, Cabin and Glycol Pressure Relief Valves	Slight to moderate heat damage from top to bottom. Heat damage to insulation on glycol lines. Debris in bottom of bay. Extensive melted plastic adhering to left-hand bulkhead and bottom.

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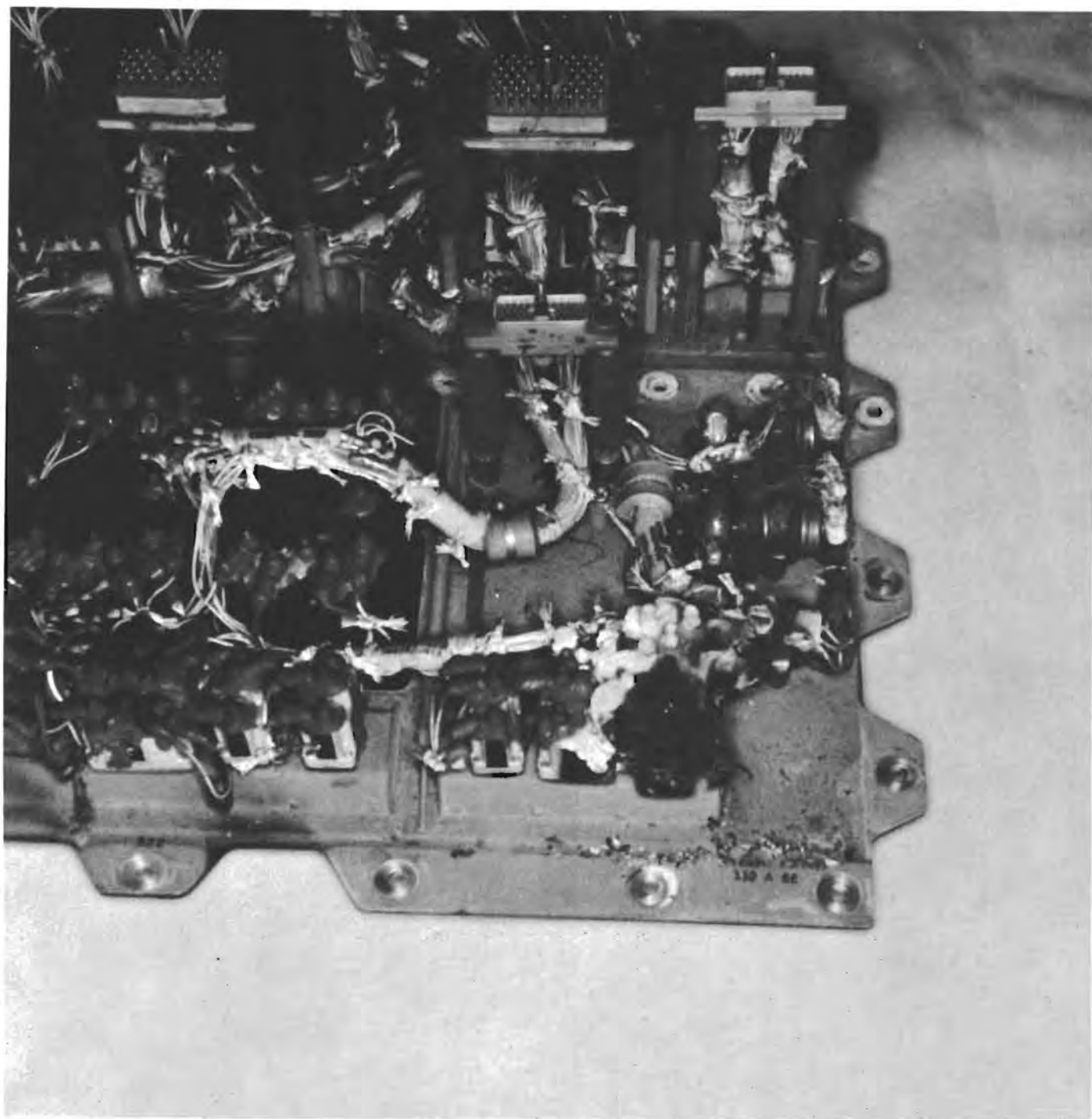


VIEW OF MAIN DISPLAY CONSOLE



MAIN DISPLAY CONSOLE	
Equipment and/or Panel	Conditions
Panel 24	Melted knobs, soot on face, burned potting on Switch S-1, burned wires around S-1 and S-4, hot jet burn inside compartment, burned insulation on glycol line. Melted Velcro on Access Panel.
Panel 25 Panel 26	Melted thumb knobs. Heavy sooting. Slight fire damage upper part Panel 25. Sooted and melted thumb wheels. Soot and heat on rear face of panel by entry around thumb wheels. Potting compound on Switch No. 6 and No. 7 shows some burning.
Panel 4 (FDAI)	Melted potting on connector. Bare wires. Soot.
Panel 5	Lower five push-buttons burned out. Heavy fire damage on face. Hot jet burn from lower left corner inside. Condensate streaks on bay walls.
Panel 6 Panel 12	Melted thumb buttons or knobs. Glass cracked. Moderate soot.
Panel 7	Melted push buttons. Broken guard rings. Burned paint. Melted potting on connectors. Hot jet burn upper area.
Panel 8	Soot heavier on left. Condensate streaks inside.
Panel 14	Hot jet burn from lower left corner. Melted push buttons. Moderate heat damage. Burned potting. Bare wires.
Panel 13 Panel 18	Thumb wheels on lower left side melted (lower thumb wheel more damaged than the two above). Rear of face plate, Switch to left of S-27 shows burned potting compound, tape around mechanical portion of switch burned away. Push buttons slightly melted. Burned paint on face. Light soot inside, heavier on left.
Panel 16	Melted Velcro. Soot. Melted plastic adhered to face. Soot inside.

MAIN DISPLAY CONSOLE (CONTD)	
Equipment and/or Panel	Conditions
Panel 15	Covers around gauges melted. Cracked glass. Knobs slightly melted. Inside, soot heavier on left.
Panel 20	Melted squelch knob. Light soot inside.
Panels 1, 2, 3, 10, 11, 19, 21, 22, 23	Slight fire damage. Soot.



INTERIOR VIEW OF PANEL 13 SHOWING DAMAGE NEAR THUMB WHEELS



LIST OF REFERENCES

REFERENCE

- 5-1 Report on Translation Controller TPS No. S/C 012 PIB 002 February 11, 1967.
- 5-2 Report on Rotation Controller TPS No. S/C 012 PIB 004 February 15, 1967.

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